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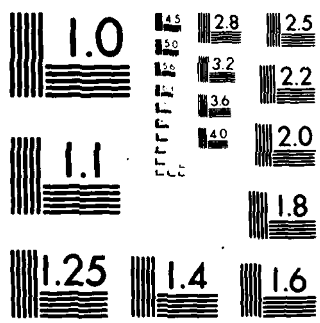

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MOBILE LOW FREQUENCY WARNING SYSTEM FEASIBILITY ANALYSIS

FINAL REPORT

15 NOVEMBER 1980

AD A092986

DCPA 01-79-C-0264
WORK UNIT 2234H
CSC/SD-80/3738

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Antenna Sharing	Dispersion
Attack Warning & Recovery	Dual Use
Contiguous 48 States	Electromagnetic Pulse (EMP)
Decision Information Distribution System (DIDS)	Emergency Broadcast System (EBS)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the results of a technical analysis and a cost estimate for a Mobile Low Frequency (LF) Warning System which is survivable against enemy attack through the use of redundancy and dispersion. The technical feasibility is shown based on shared use of AM, FM or TV broadcast station facilities under Program D-Prime by LF mobile units to blanket the contiguous 48 states with warning messages relayed from the National

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Fallout Shelter
LF Transmit Zone
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Mobile Unit (MU)
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National Warning System (NAWAS)
Natural Disasters
Program D-Prime
Radio Propagation Areas
Redundancy
Survivability

20. ABSTRACT (cont'd)

Warning Centers, or to warn of impending man-made or natural disasters and to coordinate recovery operations. Alternatives to the system architecture are discussed, and a preliminary system performance specification and cost estimate are included.

MOBILE LOW FREQUENCY WARNING SYSTEM FEASIBILITY ANALYSIS

FINAL REPORT

15 NOVEMBER 1980

Prepared for
FEDERAL EMERGENCY MANAGEMENT AGENCY
Washington, D.C. 20472

CONTRACT DCPA 01-79-C-0264
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EXECUTIVE SUMMARY

ES.1 BACKGROUND

The Federal Emergency Management Agency (FEMA) has an urgent need for a survivable national warning system, capable of disseminating warning and related information concerning natural or man-caused disasters to Federal, state, and local officials. Under contract DCPA01-79-C-0264, dated 11 April 1979, Computer Sciences Corporation was tasked to accomplish a two phase study on the potential use of mobile low frequency (LF) units in combination with fixed commercial radio and TV antenna facilities to transmit the warning data.

Phase I of the study was a preliminary analysis of the technical aspects of the basic concept. It was completed and a report entitled, "Mobile Low Frequency Warning System Study" was published 6 August 1979.

The Phase II study provided for an evaluation of the operational and economic aspects as well as more detailed analysis of technical considerations and the preparation of preliminary performance specifications. This report covers the complete analysis.

ES.2 PHASE I STUDY

The existing FEMA warning system is a leased landline network that can rapidly alert over 2000 points throughout the nation. The warning message is further disseminated from these points by siren, telephone, and radio fanout. The two weakest points of this system are the vulnerability of the complex landline network and the inadequacy and unreliability of the system for dissemination of the warning to the general public.

Earlier efforts to provide a more effective, survivable network resulted in the successful design and testing of the low frequency Decision Information Distribution System (DIDS)

concept. The technical performance and capabilities of this system were successfully demonstrated by the prototype installation at Edgewood Arsenal, Maryland. However, the project was not implemented, in part, due to the vulnerability of the 10 fixed transmitter facilities needed to cover the nation. In the era of nuclear plenty, these 10 faciiities could be considered as targets.

In order to provide a relatively survivable system that would also have the capability to provide greater official and public coverage, a new concept was proposed. The concept takes advantage of the two most practical survivability factors, redundancy and dispersion.

The proposed survivable low frequency system would use mobile units with low frequency (160-190 kHz) high power transmitters to disseminate the warning. To have suitable antenna facilities available for radiating the LF signals, the concept calls for shared use of various fixed, commercial AM, FM, or TV antenna facilities. A series of transmit zones would be established throughout the 48 contiguous states. Figure 1-1 shows a typical "transmit zone". The term transmit zone is used to identify any one of a series of general areas where 4 to 7 broadcast antenna facilities are located that support two mobile LF transmitter units (MU). The zone shown is 50 miles in diameter. The transmissions radiated from the transmit zone will cover a "propagation area" hundreds of miles in radius. Propagation area is the term used to describe the area that is covered by the signal propagated from any of the antennas in a transmit zone. The field intensity of the radio signal at the outer edge (contour of the defined propagation area) was 500 microvolts per meter (μV/m) for a 50 kw transmitter. Figure 1-2 of Section 1 of this report shows the coverage pattern provided by the initial configuration developed in the Phase I study.

Within each transmit zone there will be two mobile units (MUs). One unit will be at a broadcast facility ready to broadcast a warning without delay. The second unit will normally be enroute to or from, or at, another broadcast facility. The MUs will rotate between facilities on an irregular schedule so that an enemy can not predict their locations, thus complicating any effort to make the units a target.

The overall system would perform its function by having the active transmit units receive a warning message from a National Warning Center and retransmit the warning throughout their area, by LF. The LF receivers used in the system would be of the "demutable" type, i.e., they could be in an off or standby mode, but by means of a coded LF signal they would be automatically activated and be able to receive the warning message passed by the LF transmitter. The receivers would be located in Federal, state, and local warning center offices and activities. This would include emergency operating centers (EOCs), police and fire stations, civil defense offices, Governor's and Mayor's offices and homes, hospitals, prisons and factories. If private citizens desired they could procure their own units and receive the warning directly in their homes.

The separate operational problem of getting the initial warning to the MU is specifically excluded from this study effort. There are various possibilities to accomplish this task, including meteor burst, telephone, radio relay, adaptive HF systems, and others. For this study, it is an approved assumption that the MU will receive the warning in a timely manner.

The Phase I study demonstrated that the concept was technically feasible.

ES.3 PHASE II STUDY APPROACH

The Phase II study effort approached the analysis of the system in greater technical detail as well as from an operational and economic viewpoint. On-site surveys were made to obtain sample data on AM, FM, and TV stations. Interviews were conducted with broadcast station personnel to obtain representative data on the attitude of these personnel towards supporting the implementation of the system at their facilities. Prior to the on-site surveys, preparations were made that included a detailed map survey, and a review of available Federal Communications Commission (FCC), FEMA, and broadcast industry data on AM, FM, and TV stations and facilities. These reviews indicated potential difficulty in finding sufficient antennas suitable for modification (to permit LF transmission) in areas outside of nuclear high risk zones. As a result, consideration had to be given to using larger transmit zones than the desired 50 mile radius zone of Phase I. Additionally, the difficulty in diplexing or operating a 50 KW LF unit immediately adjacent to or on a commercial AM, FM, or TV facility may cause significant problems that can be greatly reduced by using lower transmitter power. This might require more transmit zones to provide nationwide coverage and result in increased personnel and facility requirements. Tradeoffs between these factors were evaluated.

Survey trips were made to 11 broadcast stations in Texas, 6 in Pennsylvania, to the Decision Information Distribution System (DIDS) facility at Edgewood, Maryland, and to WPIK's antenna farm in Alexandria, Virginia.

The detailed technical analysis emphasized practical approaches to providing suitable antenna facilities that would not develop excessive current and voltage levels. Figure 2-2 of Section 2 shows the work flow for the Phase II effort.

ES.4 OPERATIONAL ANALYSIS

The operational analysis addressed the following major subject areas:

- Transmit zone manning levels
- On-site protection from fallout
- Broadcast station management cooperation
- Operational procedures for pre-, trans-, and post-attack conditions
- Regulatory considerations
- Frequency assignments
- Transmit/Propagation zone review
- Physical layout

ES.5 DETAILED TECHNICAL ANALYSIS/SYSTEM DESIGN

The detailed technical analysis and systems design centered on the major task of loading an antenna structure, that was not designed for LF radiation, with a very large LF signal. LF signals in the 160 kHz to 190 kHz band have a 1/4 wave length of 1538 to 1295 feet (469 to 395 meters). Thus, there are only a limited number of broadcast antenna structures in this height range, and of those that are, many would be difficult to modify to meet the requirements.

The detailed analysis addressed, among other items:

- Antenna modifications
  - Series fed vertical radiators
  - Shunt fed vertical radiators
  - Folded unipole radiators
  - "PARAN" type antenna array
- Single side band (SSB) transmitter
- SSB receiver
- Propagation/Area coverage
- EMP Protection

ES.6 COST ANALYSIS

An equipment survey was made and costs obtained from vendors and manufacturers. Costing included all necessary equipment, system engineering, installation, operations, and maintenance costs.

ES.7 CONCLUSIONS AND RECOMMENDATIONS

Based upon the valuable data gathered during the on-site surveys, data from industry, research efforts, and detailed analysis, the following major conclusions and recommendations were made.

ES.7.1 Conclusions

The study has confirmed the feasibility of the LFMWS concept provided certain technical and operational alternatives can be applied. While the program to acquire the system will be a complex undertaking, it is a practical and viable concept which could increase warning system survivability. The following conclusions were confirmed:

1. The 48 contiguous states could be adequately covered by a mobile LF system that employs 17 transmit zones, 34 mobile LF units (2 per transmit zone), and approximately 85 modified broadcast station antenna facilities (an average of 5 per transmit zone), and some regional logistics centers. Each broadcast station area involved would have a fallout shelter large enough to house the mobile unit.

2. Low frequency ground wave propagation using single sideband suppressed carrier voice transmission is the preferred transmission mode.

3. Station surveys in two representative zones and research of industry and Government data indicate that AM, FM, and TV towers of appropriate height and configuration for LF transmission and located outside of high risk areas are very limited in number.

4. Station surveys and analysis have uncovered two viable alternatives to offset conclusion 3; the first being the use of the PARAN type antenna and the second, based on the relatively large percentage of AM, FM, or TV stations which have planned upgrade or expansion moves, suggesting the possibility of a joint venture to build new antenna facilities to serve both commercial and Government needs.

5. Station surveys in two representative zones established, almost without fail, the wholehearted and enthusiastic cooperation of broadcast station owners, managers, and technical personnel provided the LF operation did not adversely affect commercial operations.

6. Critical factors in the total system design are ground conductivity and radial system requirements, antenna height, and antenna voltage. Because of unusual situations regarding location of some broadcast stations, use of arrays by broadcasters and the newness of the PARAN concept, a program of performance tests is needed.

7. If an AM broadcast station has a tower that is a half-wave length high (at the broadcast frequency), modifications increasing its electrical height for LF are limited to those which will increase the electrical height for MF (the AM station) to no more than $.625\lambda$. This is to avoid excessive sky-wave radiation by the broadcast station.

8. A classic folded unipole design applied to a grounded tower would require a fairly high tower and also require a T or L type inductive coupling network because the tower would be considerably less than a quarter wave length. A folded unipole type of shunt feed could be applied to a shorter tower only if the tower were insulated from ground and multiple tuned at the feed point and to ground.

9. Transmitter PEP should be limited to 50 kW to reduce antenna voltage and current problems. This power limitation is acceptable for 17 transmit zones if SSB is used.

10. The system acquisition will be complex due to its size and the large number of participants with diversified interests; therefore, a program management group supported by a system engineering group should be established to implement the system. The program could be implemented on a realistic phased basis over a period of five years.

11. The estimated total cost for the system is $32,088,250 in capital cost including $4,614,500 allocable to Program D-Prime, and $7,024,698 for annual O&M, when in full operation, in current value dollars.

12. The above estimates are sensitive to the ability of industry to produce an LF receiver in the required quantities which will sell for $100 or less per unit. If the receiver were to cost $300 per unit, a procurement of 50,000 would increase the system estimated capital cost by about 31.2 percent.

13. An alternative eliminating mobile LF units but providing 85 hardened LF EBS stations would be almost as survivable, would cost about 37.9 percent more to acquire but 34.5 percent less per annum to operate. The annual savings would pay back the capital cost increase in about 5 years.

14. The LF system can serve the dual purpose of warning and recovery coordination in emergency and national disaster situations.

15. As the LF system is implemented and activated, a number of NAWAS drops to county and other local points may be eliminated, with attendant NAWAS cost reductions.

16. For the total system to accomplish its warning mission, a survivable long haul communications system is required to back up the NAWAS to get the alerting messages to the mobile units, when normal means fail.

ES.7.2 Recommendations

1. A study should be conducted to develop and define the architecture for a survivable long haul system to interconnect the national warning centers with the mobile units at antenna locations.

2. Concurrently action should proceed on establishing a program management office to implement the initial two phases of the acquisition plan provided in this report.

ABSTRACT

This report presents the results of a technical analysis and a cost estimate for a Mobile Low Frequency (LF) Warning System which is survivable against enemy attack through the use of redundancy and dispersion. The technical feasibility is shown based on shared use of AM, FM or TV broadcast station facilities under Program D-Prime by LF mobile units to blanket the contiguous 48 states with warning messages relayed from the National Warning Centers, or to warn of impending man-made or natural disasters and to coordinate recovery operations. Alternatives to the system architecture are discussed, and a preliminary system performance specification and cost estimate are included.

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SECTION 1 - INTRODUCTION

1.1 GENERAL

The Federal Emergency Management Agency (FEMA) has an urgent need for a survivable national warning system, capable of disseminating warning and related information concerning natural or man-caused disasters to Federal, state, and local officials. Under contract DCPA01-79-C-0264, dated 11 April 1979, Computer Sciences Corporation was tasked to accomplish a two phase study on the potential use of mobile low frequency (LF) units in combination with fixed commercial radio and TV antenna facilities to transmit the warning data.

Phase I of the study was a preliminary analysis of the technical aspects of the basic concept. It was completed and a report entitled, "Mobile Low Frequency Warning System Study" was published 6 August 1979. The study showed that the basic concept was feasible from a technical viewpoint.

As a result, the contract option for the Phase II study was exercised. Phase II provides for an evaluation of operational and economic aspects as well as the preparation of preliminary performance specifications. This report covers the complete study.

1.2 SCOPE

Sections 1.3 and 1.4 provide a summary of the Phase I Study including problem definition, system concept, and the Phase I Study conclusions and recommendations. Appendix A provides the Executive Summary from the Phase I report published in August 1979.

Section 2 discusses the Phase II approach.

Section 3 covers the analysis of significant operational factors including:

- Operational Requirements
- Regulatory Matters and their Impact
- Frequency Analysis
- Broadcast Station Survey Data
- Program D-Prime Impact

Appendix B provides transmit zone maps developed during Phase II.

Section 4 covers the detailed system design. Preliminary performance specifications are provided in Appendix C. Appendix D provides sample calculations.

Section 5 provides a description of the concept developed after reevaluation and refinement, during the Phase II Study.

Section 6 provides a suggested acquisition plan.

Section 7 addresses the cost estimate for both acquisition and operation and maintenance (O&M).

Section 8 provides conclusions and recommendations on the total system concept.

1.3 BACKGROUND (PHASE I)

This paragraph summarizes the results of the Phase I feasibility analysis. Detailed information is available in the 6 August 1979 draft report entitled, "Mobile Low Frequency Warning System Study", the Executive Summary of which is included as Appendix A to this report.

The FEMA has the requirement to provide a survivable national warning system to warn Federal, state, and local officials and the general public in the event of actual or impending enemy attack or natural or man-caused disaster.

The existing FEMA warning system is a leased landline network that can rapidly alert over 2000 points throughout the nation. The warning message is further disseminated from these points by siren, telephone, and radio fanout. The two weakest points of this system are the vulnerability of the complex landline network and the inadequacy and unreliability of the system for dissemination of the warning to the general public.

Earlier efforts to provide a more effective, survivable network resulted in the successful design and testing of the low frequency Decision Information Distribution System (DIDS) concept. The technical performance and capabilities of this system were successfully demonstrated by the prototype installation at Edgewood Arsenal, Maryland. However, the project was not implemented, in part, due to the vulnerability of the 10 fixed transmitter facilities needed to cover the nation. In the era of nuclear plenty, these 10 facilities could be considered as targets. The FEMA concept of the use of mobile LF transmitters, utilizing prepositioned antennas on commercial broadcast facilities, presents a potential solution to this survivability problem and employs a technique that permits alerting of the general public by home radios.

The overall objective of the Phase I study was the technical evaluation of the mobile unit concept. Specifically, the four major Phase I objectives were:

1. Define and evaluate the basic system design concept and important related factors
2. Provide a preliminary antenna interface design
3. Establish a preliminary design for LF mobile transmitter units
4. Provide an estimated cost range for a technically sound system.

The basic system guidelines for the LF facility design were to:

1. Provide an LF voice communication system (about 3 kHz bandwidth) that will cover the 48 contiguous states
2. Make use of existing commercial antenna facilities
3. Incorporate survivability features that ensure system availability in pre-, trans-, and post-attack environments
4. Develop a cost effective system.

1.4 BASIC CONCEPT (PHASE I)

In order to provide a relatively survivable system that would also have the capability to provide greater official and public coverage, a new concept was proposed. The concept takes advantage of the two most practical survivability factors, redundancy and dispersion.

The proposed survivable low frequency system would use mobile units with low frequency (160-190 kHz) high power transmitters to disseminate the warning. To have suitable antenna facilities available for radiating the LF signals, the concept calls for shared use of various fixed, commercial AM, FM, or TV antenna facilities. A series of transmit zones would be established throughout the 48 contiguous states. Figure 1-1 shows a typical "transmit zone". The term transmit zone is used to identify any one of a series of general areas where 4 to 7 broadcast antenna facilities are located that support two mobile LF transmitter units (MUs). The zone shown is 50 miles in diameter. The transmissions radiated from the transmit zone will cover a "propagation area" hundreds of miles in radius. Propagation area is the term used to describe the area that is covered by the signal propagated from any of the antennas in a transmit zone. The field intensity of the radio signal at the outer edge (contour of the defined propagation area) is 500 microvolts per meter (μV/m). Figure 1-2 shows the coverage pattern provided by the initial configuration developed in the Phase I study. Note that overlapping of coverage areas will be required in order to provide complete CONUS coverage.

The basic operational concept for the survivable LF warning system is described below.

A series of transmit zones will be defined that have 4 to 7 antennas that may be modified to radiate 50 KW LF signals. The number and location of the transmit zones will be selected so that all parts of all 48 contiguous states are within the 500 μV/m contour lines developed.

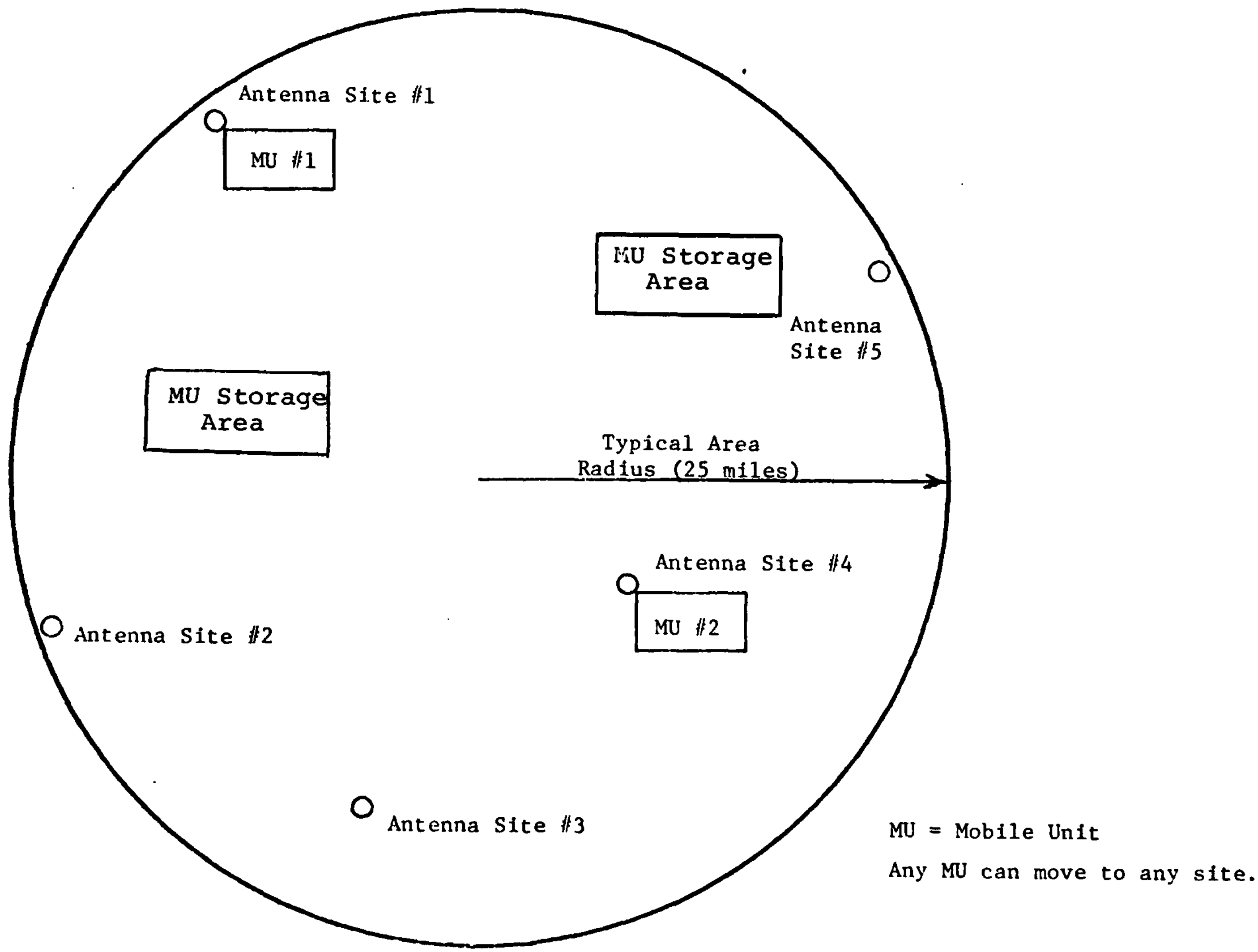


Figure 1-1. Typical Transmit Zone Utilizing Two Mobile Units and Five Antenna Sites

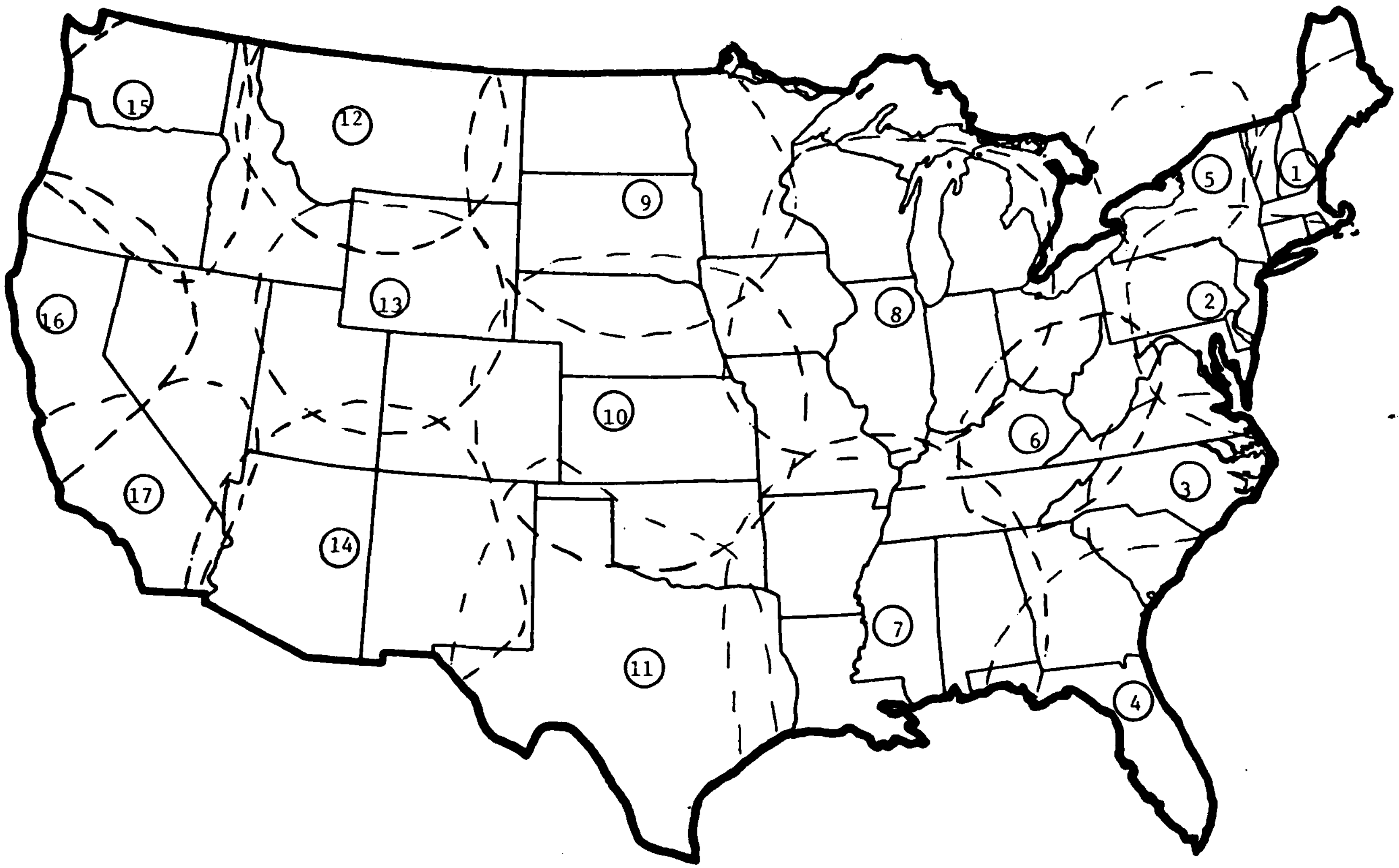


Figure 1-2. LF Groundwave Range Pattern at 500 $\mu V/m$ for Selected 50 kW Transmitter System.

Within each transmit zone there will be two mobile units. One unit will be at a broadcast facility ready to broadcast a warning without delay. The second unit will normally be enroute to or from or at another broadcast facility. The MUs will rotate between facilities or on an irregular schedule so that an enemy can not predict their locations, thus complicating any effort to make the units a target.

The overall system would perform its function by having the active transmit units receive a warning message from a National Warning Center and retransmit the warning throughout their area, by LF. The LF receivers used in the system would be of the "demutable" type, i.e., they could be in an off or standby mode, but by means of a coded LF signal they would be automatically activated and be able to receive the warning message passed by the LF transmitter. The receivers would be located in Federal, state, and local warning center offices and activities. This would include emergency operating centers (EOCs), police and fire stations, civil defense offices, Governor's and Mayor's offices and homes, hospitals, prisons and factories. If private citizens desired they could procure their own units and receive the warning directly in their homes.

A separate operational problem is that of getting the initial warning to the MU. There are various possibilities to do this including meteor burst, telephone, radio relay, adaptive HF systems, and others. The means of contacting the MU is not an element of this study effort. For this study it is an approved assumption that the MU will receive the warning in a timely manner.

SECTION 2 - STUDY METHODOLOGY

This section covers the Phase II study approach and data collection efforts. The CSC study methodology is patterned after the work breakdown and work flow diagrams of Figures 2-1 and 2-2.

2.1 STUDY APPROACH (PHASE II)

The Phase I study addressed the feasibility of the mobile LF warning system concept from a theoretical technical viewpoint and determined that such a system is feasible.

The Phase II study effort approached the development of such a system from a more detailed technical, operational, and economic viewpoint. On-site surveys were made to obtain sample data on AM, FM, and TV stations. Interviews were conducted with broadcast station owners, managers, engineers, and operating personnel to obtain representative data and to determine the attitude of these personnel in supporting the implementation of the system at their facilities.

Conferences and telephone conversations were held with manufacturers' representatives, as well as engineers and consultants on hardware interfaces, equipment, and system design. Meetings were also held with Federal Communications Commission (FCC) and FEMA personnel.

2.2 SURVEY PREPARATION

In order to obtain realistic data on a sampling of broadcast stations, on-site surveys were essential. Prior to the surveys, preparations were made that included a detailed map survey, and a review of available FCC, FEMA, and broadcast industry data on AM, FM, and TV stations and facilities. These reviews indicated potential difficulty in finding sufficient antennas suitable for modification (to permit LF transmission) in areas outside of nuclear high risk zones. As a result, consideration was given to larger transmit zones than the desired 50 mile radius zone. Additionally, the difficulty in diplexing or operating a 50 KW LF unit immediately adjacent to or on a commercial AM, FM, or TV

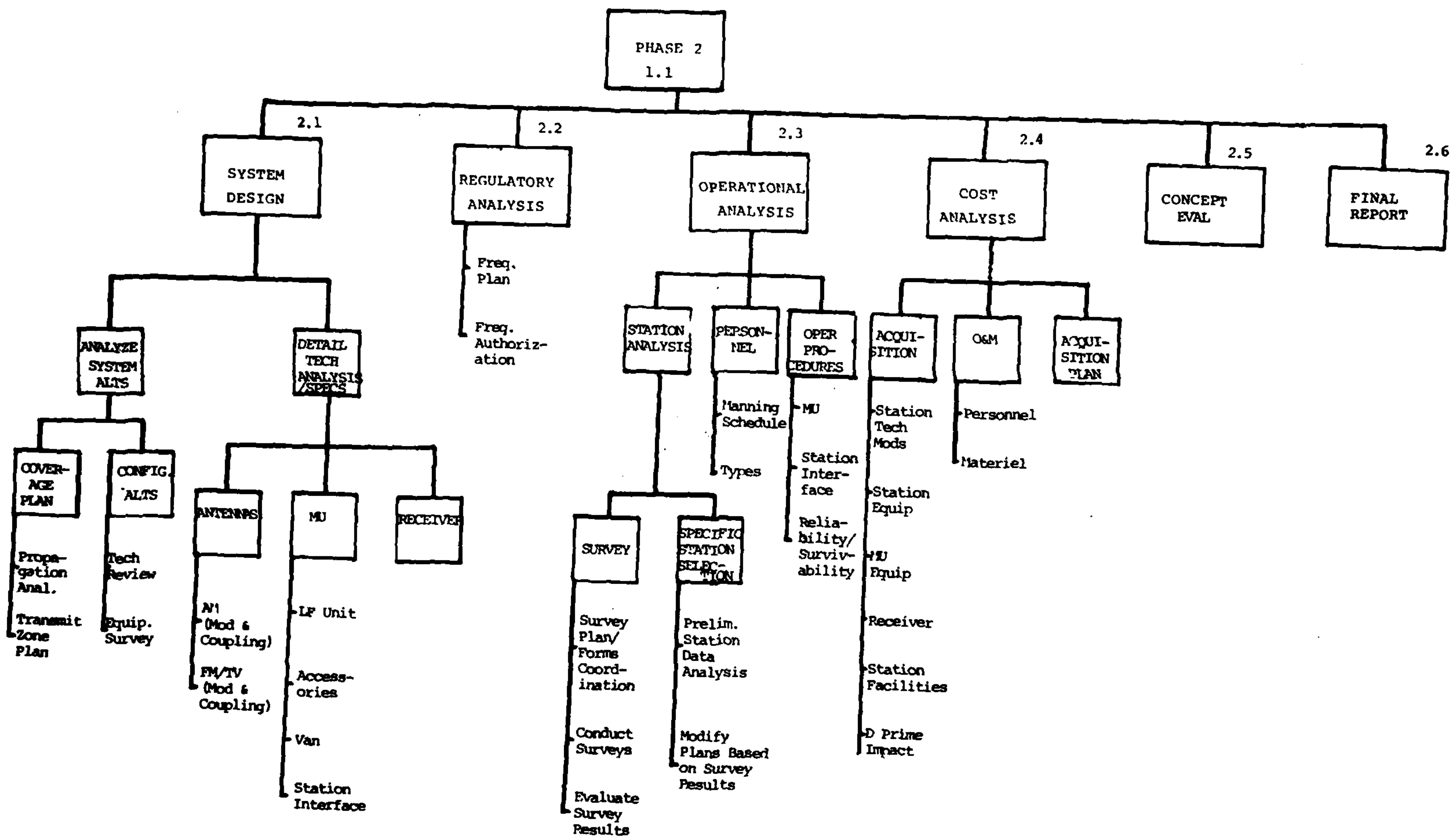


Figure 2-1. Phase II Work Breakdown Structure.

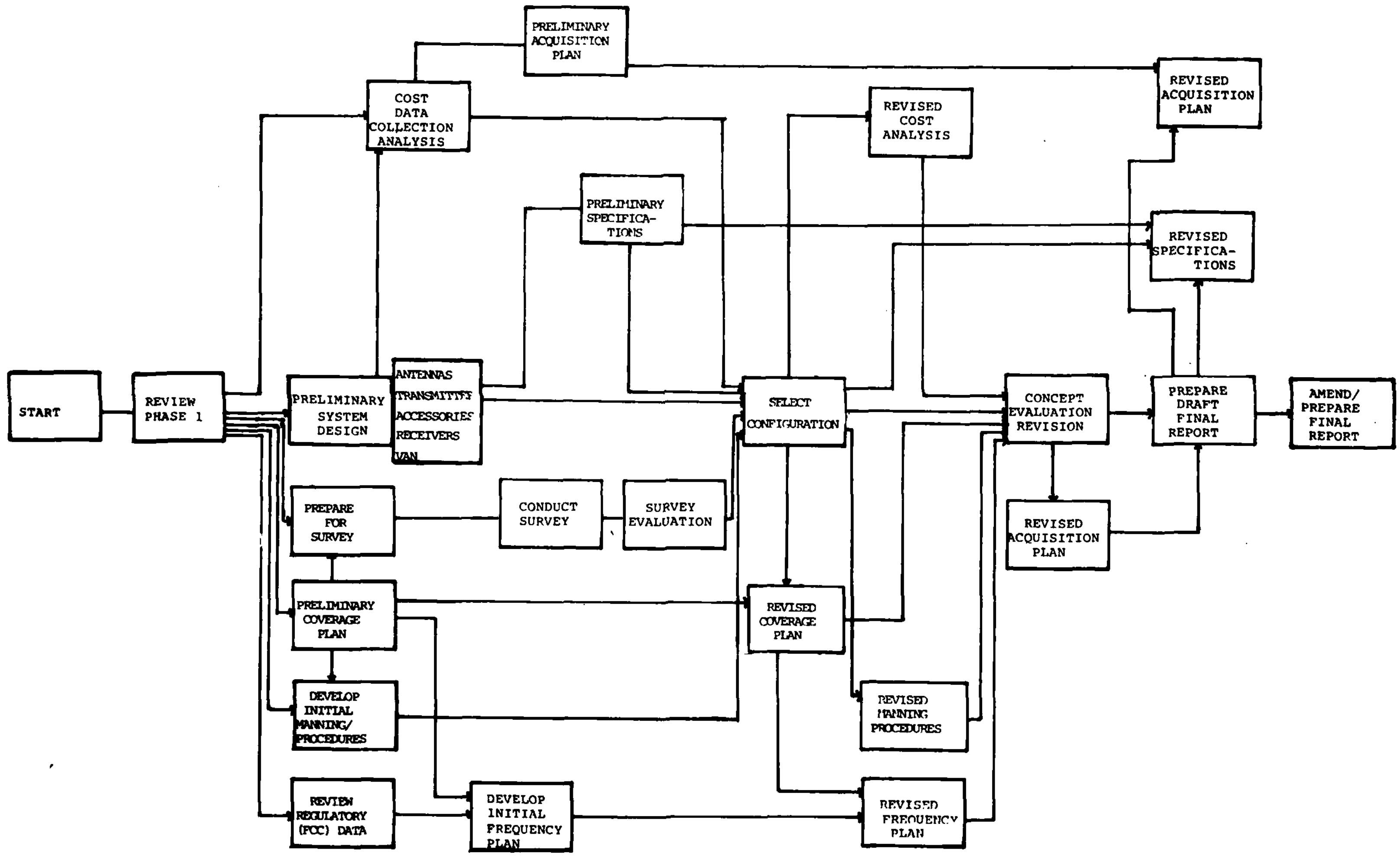


Figure 2-2. Phase II Work Flow.

facility may cause excessive problems that can be greatly reduced by using lower power. This would require more transmit zones to provide nationwide coverage and result in increased personnel and facility requirements. Tradeoffs between these factors were evaluated.

Survey trips were made to 11 broadcast stations in Texas, 6 in Pennsylvania, to the Decision Information Distribution System (DIDS) facility at Edgewood, Maryland, and to WPIK's antenna farm in Alexandria, Virginia. A discussion of data collected and survey results are included in Section 3.

SECTION 3 - OPERATIONAL ANALYSIS

This Section addresses the many operational considerations that may impact the overall system performance and cost.

3.1 OPERATIONAL CONCEPT

As previously stated, the basic operational concept is to have two mobile LF units (MU) assigned to a transmit zone. One of the two MUs will always be operational and ready to relay a warning message via one of the 4 to 7 joint use Government-commercial antenna facilities in the transmit zone. The propagation areas covered by the total group of transmit zones will provide complete coverage of the contiguous 48 states (CONUS). Thus, any office or home in CONUS, equipped with the compatible receiver, would be able to receive the FEMA warning or informational message.

3.1.1 Transmit Zone Manning

The major recurring cost for the proposed system is the cost for the operations and maintenance personnel. There are several factors that can impact this manning problem as indicated below:

- Variety of skills required (e.g., LF transmitter O&M, Power Unit O&M, Vehicle Driver)
- Irregularity of work location and large distance between locations
- Level of redundancy required (routine times versus alert conditions
- Civil Service or contractor manning.

The minimum requirement is for one mobile unit per transmit zone to be on site and available 24 hours per day, 7 days per week. Thus for a week (7 x 24 = 168 hours) there would be a requirement for $\frac{168}{40}$ or 4.2 men. Considering vacation and sick time allowances one team could be manned by 5 men. With proper scheduling and limited overtime, this one team could also move the alternate MU between sites.

This arrangement does not provide a high redundancy level. A more satisfactory (but more costly) arrangement would have one five man team for each MU. One MU would be the primary, operational unit. The second would be at an alternate site, manned and ready to immediately disseminate emergency warning or informational messages in the event the primary unit was unable to accomplish the mission promptly. Thus, there would be both dispersion and redundancy except for the travel time between sites and the time one of the units is down due to maintenance problems or enemy action.

Alternative solutions are possible, including a compromise plan where, under routine conditions, there is only one 5 to 7 man team. This team would be increased by qualified, paid or volunteer personnel under crisis buildup or emergency conditions.

3.1.2 <u>On-Site Protection</u>

Safety of the system personnel and equipment must be a key feature of a survivable network. It is not the objective of the concept to provide hardened facilities that can withstand the effects of direct or nearby nuclear weapons hits. Under the concept, the basic protection is provided by selection of operating locations outside of high risk areas. However, protection from the fallout, which would cover much larger areas of the country, is a significant but solvable problem. Such protection can be provided to personnel and their working environment (i.e., the MU) by having the vehicle routinely drive into and operate from an adequate shelter. This shelter may be above ground with suitable cover, or it may be a more secure, simple underground structure with the earth above providing the necessary radiation shielding. A below ground structure also provides excellent protection against low levels of blast overpressure. Each site must be evaluated on an individual basis to determine the most cost effective approach to obtain the desired level of protection.

The limited number of suitable commercial antenna facilities found to be located in the desired transmit zone areas will result in stations being selected that are closer to high risk areas than desired. This increases the need for the use of simple protected locations for the MU operation.

When selecting the protected area for the MU, consideration must be given to the ease of access to the antenna, to the power supply, and to the broadcast station facilities important to the MU operator on duty.

3.1.3 Station Management Attitude

This mobile LF concept is totally dependent upon the cooperation of the broadcast station owners and management. This previously unknown factor, management attitude, was sampled by phone and by on-site surveys with excellent results. There was general willingness to support the FEMA effort both by joint use of existing facilities and projected new facilities. This was based on the Government system not interfering with the station's regular operation, and the Government funding its share of costs.

3.2 SYSTEM OPERATIONS AND CHARACTERISTICS

Operational procedures must be keyed to:

1. The capability to provide a prompt and reliable warning of impending attack.
2. Survival, so that further warning and coordination messages may be forwarded during trans- and post-attack phases.

In determining what the LF operations scenario should be to accomplish the above, the following important factors should be considered:

1. It may not be possible to avoid placing some LF facilities within or near risk areas.

2. Mobility should not be completely dependent on the functional capability of the truck in which the facility is installed. Truck breakdown and maintenance should not disable the warning function of the system.

3. To conserve fuel, people, and equipment, mobility should only be utilized when conditions require it, except for periodic tests or exercises.

4. A broadcast station tower might survive a nuclear event, but buildings and vehicles could be severely damaged by blast and thermal effects. If possible, the LF facilities should be placed in a protected location and away from the tower.

As described earlier, the proposed concept developed an operational scenario that had 17 transmit zones, each containing 4-7 towers configured to radiate simultaneous regular broadcast programs and also the LF warning messages. Two mobile LF facilities in each zone would use the towers in quasi-random fashion, with one MU operational at all times. If at all possible, no antenna would be within a known risk area. However, it has become evident that such an ideal situation may not be achieved within reasonable limits of expense, and, therefore, the concept was modified to accept compromises without radically affecting the mission effectiveness.

Those broadcast station towers which can be economically modified to radiate an effective LF warning over the required land area are few and far between, and are usually located within known risk areas. For example, WJR, Detroit, which was used during DIDS tests some years back, has an ideal 700 foot radiator, suitable for high power diplexing (50 KW) but is within the high risk area. A rigid application of the initial guidelines would eliminate this station, as well as many other ideal stations from consideration. The motivations behind, on the one hand, establishing, building, and operating a high powered broadcast facility for profit (and in the public service) and, on the other

hand, establishing, building, and operating a survivable warning system for emergency use, are not compatible with each other. The first has to be at the center of its densely populated service area--usually a high risk zone--and the second must not be in a risk area but should be at the center of a much larger warning area, and situated to radiate to places densely populated and places not normally densely populated. It must survive catastrophic events occurring within or near the high risk portions of this larger area.

3.3 OPERATIONAL PROCEDURES AND SCENARIOS

In order to meet the requirements and characteristics discussed above and adapt to those broadcast facilities which will be available and useable, operational scenarios should be established which are keyed to the stage of any emergency. The following paragraphs describe possible operational scenarios along these lines.

3.3.1 Pre-Attack/Emergency Phase

During this phase, the primary, or most optimum station tower is always used, and the primary transportable LF facility utilizing this tower is only moved for periodic exercises and tests. This will be true even if this optimum facility is in a high risk area. The point here is that, for the most important warnings of all, those involving impending attack or warning and recovery messages related to civil disorder or natural catastrophic events, the optimum LF transmission should be available. The secondary transportable LF facility may also be based here, for security and efficient upkeep, except that once a month, or another reasonable period, it may travel to another tower location to participate in tests and training exercises for a short period. As long as no real emergencies arise, this routine can continue with the secondary transportable LF facility utilizing from 3 to 6 secondary towers within its transmit zone for the periodic test and training mission, in a quasi-random manner. As soon as an emergency situation is identified, this scenario undergoes a planned modification:

1. The secondary LF unit moves to one of the secondary towers--outside the risk zone--and initiates operation.
2. Upon direction to issue an attack warning, both stations alternatively broadcast the message for a prescribed period of time.
3. Sufficiently prior to the estimated time of attack, the primary station broadcasts its final warning message and becomes mobile, evacuating the risk location and proceeding with priority (state police or military escort) to another secondary tower outside the risk zone. Upon arrival it becomes operational. Upon actual attack, hopefully, both LF transportable facilities survive.

3.3.2 Trans-Attack/Emergency Phase

During the trans-attack phase, both transportables go into their quasi-random routine of one in operation and, if conditions permit, the other in motion between remaining available towers. Whether either of them ever returns to any tower within a high risk area depends on the situation. Similarly, how towers in low risk areas are utilized depends on whether movement is possible and other specifics of the situation. Through error, or mishap, a low risk area may have been affected and the tower in that area rendered inoperable, or radiation problems might render human access inadvisable. For these reasons, some kind of a command and control communications network should exist between the transportable LF facilities themselves and their tower stations. LF receivers at the tower stations and MF, UHF FM or TV sound channel receivers in the LF transportables could conceivably provide for this. Reception of scheduled, voice coded transmissions from a broadcast station would indicate its continuing availability, while reception of voice codes in the LF station transmission would provide for changing of movements and schedules from the prescribed pattern. Lack of reception of coded transmission from the broadcast station would mean that the

facility was inoperable, or had been taken over by unfriendly elements, and going there would be either wasted time or hazardous for the transportable equipment and crew. This procedure would continue until either the ability to operate the LF warning system is destroyed or the trans-attack phase terminates.

3.3.3 Post-Attack/Emergency Phase

Immediately upon inception of the post-attack phase, one LF unit returns, if possible, to the primary station. If this is not possible, it goes to the next most optimal tower. The second LF unit goes to the most logical other tower, or stays where it is, and both function as required during return to normal conditions, remaining alert, however, should another attack become evident during this period.

3.4 OPERATIONAL EFFECTIVENESS

The above scenario description has treated the numbered factors in Paragraph 3.2 in the following ways:

1. LF facilities in risk areas - proposed a way to utilize and take advantage of broadcast stations in or near risk areas.
2. Dependence on Prime Movers - See below.
3. Conservation of Fuel, People, and Equipment - Use of mobility only when needed.
4. Survival - See below.

Regarding dependence on prime movers, it is suggested that it will be better to construct the transportable LF facility in a 4 or 8 wheeled trailer to be hauled by 6 or 10 wheeled tractor prime mover, or in a shelter that could be placed on a flat bed prime mover when transportability is required. Not making the communications unit an integral part of the prime mover will allow the prime mover to be substituted, in case of engine or other

mechanical trouble. It would also allow contracting for prime mover service on a lease basis, or using armed services (National Guard) movers if needed, depending on the situation.

Regarding survival, the trailer housing the equipment may be made to appear as a moving van so that its movements may be kept as inconspicuous as possible, both from local visual and long distance electronic observation, possible by satellites. In addition to this, the trailer should not be parked close to the base of the tower, since this is the area of an intense electrical field, where in case of malfunction or misadjustment there is a possibility of all metallic objects becoming "Hot" with induced radio frequency energy. In this exposed position, there is also a greater possibility of damage and physical injury due to blast, thermal, and radiation effects, as well as the hazard of falling tower parts should that structure not survive. For these reasons, the planned shelter to house generators and other facilities should be enlarged sufficiently, and provided with R.F. feed-throughs and adequate ventilation so that the trailer can be parked inside. At the very least a depression in the ground should be provided away from and out of range of the tower structure--probably adjacent to the shelter.

3.5 LOGISTICAL SUPPORT

Logistics will be somewhat simplified by the adoption of the operational concept described above. For one thing, the transportable units only have to be logistically supported in their extreme environment during a trans-attack phase, or, at worst, just before, during, and just after it. Therefore, while such logistics would have to be tested during exercise periods, their actual provision may be contemplated for a fixed period of time of, say, 30 days. Personnel to man the LF units may be trained and may reside at the primary station locations, and only depart on an extended basis for the most trying conditions of civil, natural, or military disaster and consequences.

3.6 LOCAL VS TOTAL APPLICABILITY

The above described conditions are related to a single zone; however, with some variance they would apply to all of the 17 transmit zones now contemplated. Under certain conditions all zones would pass from one scenario phase to another simultaneously; however, civil disorder or natural disaster could require only a single or a few zones to react to the event demanding attention.

3.7 REGULATORY MATTERS AND IMPACTS

Early in the process of analysis for Phase II, a meeting was held with the Emergency Communications Branch of the Federal Communications Commission (FCC). The meeting was also attended by representatives of FEMA and of the FCC Broadcast Branch. The following relates to this meeting, as well as meetings and discussions with broadcast station personnel.

3.7.1 Frequency Authorization

The intended operating frequency band for the LFMWS is 160-190 Hz. The intended mode of emission, which is SSB single-channel voice with suppressed carrier (A3J) requires an operating bandwidth of 3 kHz. Ten 3-kHz channels will therefore be stacked within the 160-190 kHz band and will be selectively assigned to the 17 intended transmit zones. This band, in Region 2, is allocated to the fixed service. Although the system is called LFM (Mobile) WS, it does not operate while in motion--it merely uses transmit units that have a capability of moving from one tower location to another, but it only operates in a fixed station mode. Since there will be 17 transmit zones, each containing an average of five transmitter locations, eighty-five transmitting station locations will have to be authorized to radiate up to 50 kW PEP in a 3 kHz bandwidth in this band. The frequency allocation plan discussed in Section 5.1.2 and represented by Figure 5-6 of this report should be presented to the Interdepartment Radio Advisory Committee (IRAC) at an appropriate time for consideration.

This frequency band was authorized for use by the DIDS a number of years ago, and it is expected that it will be possible to renew the authority. However, there is a possibility that some change in channel allocations to the various zones may have to be considered, if interference situations between this plan and other users of the band materialize. Although the FCC does not assign frequencies to Government users (IRAC does), the FCC advises that activity in the 160-190 kHz band at present consists of some radio location operations and communications by oil companies to the off-shore rigs. In addition, it is understood that use of this band by unlicensed experimenters and hobbyists is allowed--probably on a non-interference basis and at very low power. There should be no problem with the latter, but it may be necessary to shift channels, particularly in zones encompassing the off-shore drilling operations off the east and Gulf coasts.

Other than these matters, nothing is expected to complicate authorization to proceed, as planned, with regard to frequencies.

3.7.2 Broadcast Station License Modifications

In those instances involving changes to broadcast stations' vertical radiators to accommodate the LF transmitter, (such as adding an umbrella top-load, a folded unipole, drop wires to enhance the diameter or extending radial systems), the broadcast station antenna radiation efficiency will benefit, as this will improve the coverage of the stations. Under such conditions, the FCC will require an application from the broadcast station (which may involve consulting engineers) for authorization under the new conditions and for modification to the broadcast license.

An example of this is WPIK in Virginia, near Washington, D.C. When WPIK added a folded unipole kit to its AM tower, to improve the bandwidth of the antenna system, a side effect was enhancement of the coverage of the station. The FCC modified

the license, reducing the authorized power output to the antenna from 5000 to 3950 watts--to maintain status quo on coverage and continue to protect other stations using the same frequency.

The cost of such new applications, including the consultants, will probably have to be borne by FEMA. CSC cost estimates include amounts to cover these items.

3.7.3 Broadcast Station Construction Permits

In those instances involving a move of a broadcaster to a new location and a joint venture with FEMA to provide a new antenna optimized for both MF and LF use, the cost of the application for construction permit and license will be borne by the broadcaster. Also, the broadcast consultants will have to include in their engineering calculations the improved radiation characteristics of the new antenna structure, which will be optimized to the degree possible for the joint MF and LF use.

3.7.4 Environmental Impact Statements

Any environmental impact analysis and resulting reports, or statements concerning modification to an existing broadcast facility (including extension of the ground radial system), will be for the account of FEMA. Environmental impact analyses and statements relating to joint ventures resulting in broadcast station moves and upgrades may be funded by prorating their costs in proportion to the main division of costs between the broadcast station and the Government for the joint venture.

3.8 SYSTEM TRANSMIT/PROPAGATION ZONE REVIEW

An analysis of FEMA, FCC, and broadcast station data was conducted to identify radio and television stations in optimum locations in each of the 17 transmit zones.

It was determined that, in many zones, ideal concentrations of appropriate towers do not exist. Further research revealed that most zones will be larger and of irregular shape (not circular with a 50 mile diameter). Selection of final candidate stations will require further research and site visits which are beyond the scope of this study phase.

3.8.1 Broadcast Station Identification by Transmit Zone

A literature survey was conducted of broadcast stations located in optimum areas in each zone in order to select prospective candidates. Selection was based on their locations in relation to the respective propagation zones and avoidance of high risk areas. Maps and lists of stations in each zone are included in Appendix B.

3.8.2 Transmit/Propagation Zone Identification/Configuration

It has been determined that the United States may be divided into 17 transmit zones. This was arrived at by calculating low frequency groundwave patterns at 500 micro-volts per meter using 50 kW transmitters and modified broadcast station antennas which will offer less than optimum power efficiency because of their short height for LF.

3.9 TRANSMIT ZONE SURVEYS

For the purposes of this phase of the LFMWS study, two out of the 17 candidate transmit zones were surveyed by documentation analysis, telephone, and finally, field trips.

3.9.1 Area Selection

The following rationale was used for selection of the survey areas:

1. The geographical locations would provide coverage of the propagation zones.
2. The station locations were not in high risk areas.
3. The areas would have a concentration of candidate antennas.

The areas chosen met all three of these conditions. This was not the case for other areas and stations considered. Many were so far from the desired transmit zones that selection would have adversely impacted propagation coverage upon movement of the mobile units.

3.9.2 Texas Survey

The Texas survey consisted of visiting 11 broadcast stations located in 10 cities. Each station was approached as a separate entity in order to perform a thorough analysis of management attitudes and potential operational and technical problems which would exist if the program were implemented. As a result, a real-world view of the industry, its people, their attitudes, and the state-of-the-art technology were observed. Owners, managers, and engineers made significant contributions by offering their comments, ideas, and suggestions. All stations indicated a willingness to participate in the program and all survey objectives were satisfied. Figure 3-1 represents the Texas area surveyed.

3.9.3 Pennsylvania Survey

The Pennsylvania survey involved the evaluation of six ideally located broadcast stations in six different cities. A primary purpose of this second survey was to take another look at the broadcasting industry in order to get a good overview of potential problems which may be encountered in another part of the country. Out of the six stations surveyed, it is felt that only four are candidates for the Low Frequency Mobile Warning System. These stations are located in Berwick, Lewistown, Sunbury, and Williamsport. Hazleton and Pottsville are questionable candidates. WVCD, Hazleton, plans to build a new tower because their present 408 ft. antenna has deteriorated to such a state that it probably will not hold up much longer. This station cannot be used because the present tower is being replaced in a time frame that is too short to go into a joint venture. Later, this station can be reviewed for possible application of a PARAN alternative. WPPA, Pottsville, cannot be used because they have an array of five 180 ft. towers which are too short, and the towers are arranged in an "X" configuration which is not suitable for a PARAN. WAVT, the FM affiliate is also 180 ft. high and is located on a mountain top. Land exists north of the WPPA array where a separate PARAN might be built. This could be investigated further if it appears desirable at a later date.

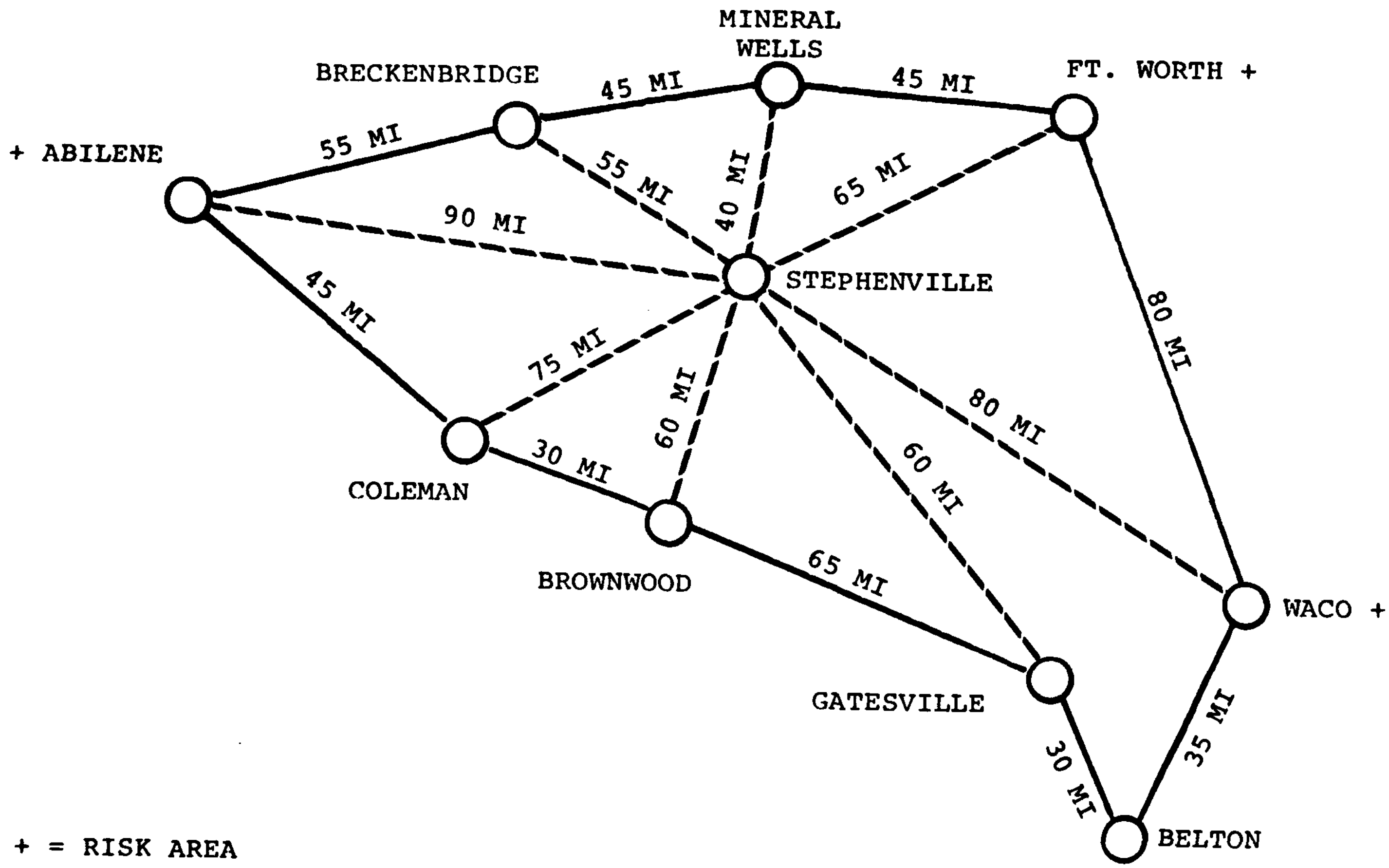


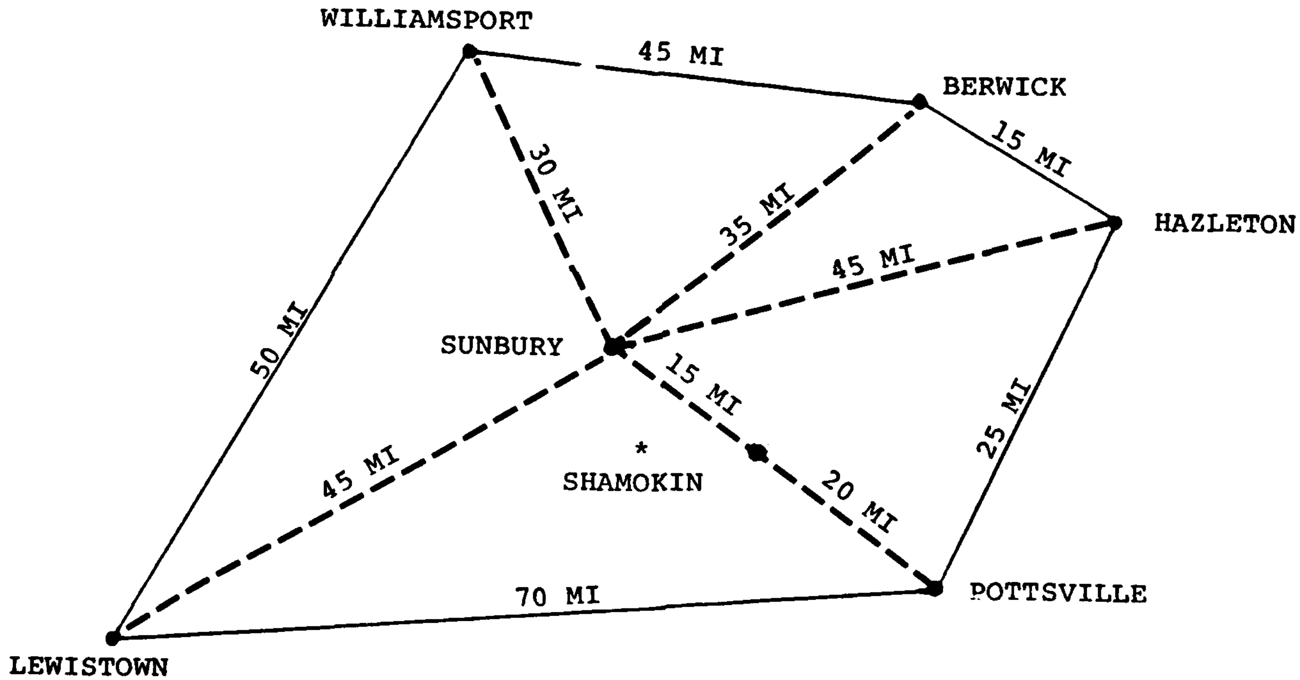
Figure 3-1. Texas Survey Area.

Although not visited, WISL, Shamokin, was contacted. A telephone conversation with the Chief Engineer established that there is an array of four 190 ft. towers located on 34 acres. This station is a possibility because, even if the array could not be used, there is adequate space for a PARAN configuration.

Figure 3-2 shows the Pennsylvania area surveyed.

3.9.4 Management Attitude Evaluation

The response of management at each station was positive; however, there were some concerns. For example, WBAP at Fort Worth is presently diplexing on another station's array system and has encountered transmitter problems because of top load icing. Even though they indicated a willingness to participate in the program, they are reluctant to allow installation of a top load on their recently built new tower. None of the stations had objections to adding to their radial systems or to building shelters on their property. The primary concern of management would be shutting down their transmitters to effect modifications which could cost them revenue. Another concern voiced by the manager of WKOK, Sunbury, PA, was that a clear cut agreement would have to be drawn up on who would be responsible for Government equipment and how maintenance and emergency repairs would be handled. All were extremely interested in the possibility of getting emergency power systems if they participated. Several indicated a desire to embark upon a joint venture with FEMA to build a new antenna facility at a new location which would serve both interests. In summary, if modifications can be accomplished at the sites with minimal impact on their operations, management at all the surveyed stations would fully support the program.



* NOT VISITED

Figure 3-2. Pennsylvania Survey Area.

3.9.5 Operational/Technical Findings

There are three possible modification alternatives appropriate for stations surveyed. The first is to modify and diplex on the existing tower. Second, a Continental Electronics four tower 200 ft. (61 meters) antenna system called "PARAN", or a similar configuration, would be an acceptable alternative to be used at a site like KCMS, Gatesville, Texas, where the existing tower is short [only 150 ft. (45 meters) high], and where there is adequate space available to install the PARAN array and a radial system. A PARAN could also be built around an existing single tower or the center tower of an in-line array, be separately fed and use the existing radial system. Alternative three would be joint ventures with broadcasters who have plans to construct stations in new locations. In this case a station would finance the portion which they would have to pay if they were going to build only for themselves, and FEMA would fund the difference required for additional modifications needed for the site, tower and radial system to be used at low frequencies.

3.9.6 Summary and Conclusions

1. Station management will respond in a positive manner if favorable inducements are offered which will enhance their operations.
2. The majority of the stations which will most likely be selected are not presently part of the Broadcast Station Protection Plan (BSPP); therefore, there will be some impact on Program D-Prime.
3. A thorough site survey will have to be conducted at all station locations in all zones to select the most feasible modification alternative.

Table 3-1 summarizes the various configurations of the Texas stations surveyed and notes special problem areas.

Table 3-2 provides similar data for the stations surveyed in Pennsylvania.

Table 3-1. Summary of Texas Survey Data

CITY	STATION	MODE(S)	TOWER HEIGHT(S)	MANAGEMENT ATTITUDE	BSPP	FEASIBLE MODIFICATION
Abilene	KRBC	TV	543'	Positive	Yes	Modify Antenna
Belton	KTON	FM	400'	Positive	No	Modify Antenna
Breckenbridge	KSTB	AM/FM	200'	Positive	No	Joint Venture
Brownwood	KOXE	FM	490'	Positive	No	Joint Venture
Coleman	KSTA	AM/FM	240'	Positive	No	Joint Venture
Ft. Worth	WBAP	AM	650'	Positive	Yes	Modify Antenna
Gatesville	KCMS	FM	150'	Positive	No	PARAN
Mineral Wells	KORC/KWMT	AM/FM	230/200'	Positive	No	Joint Venture
Stephenville	KSTV/KWWM	AM/FM	200'	Positive	No	Joint Venture
Waco	WACO/KHOO	AM/FM	400'	Positive	No	Joint Venture
Waco	KWTX	AM/FM	1000'	Positive	Yes	Modify Antenna

Table 3-2. Summary of Pennsylvania Survey Data

CITY	STATION	MODE(S)	TOWER HEIGHT(S)	MANAGEMENT ATTITUDE	BSPP	FEASIBLE MODIFICATION
Berwick	WBRX	AM	200'	Positive	No	Joint Venture
Hazleton[1]	WAZL/WVCB	AM/FM	408'	Positive	No	PARAN
Lewistown	WKVA	AM	240'	Positive	No	PARAN
Pottsville[2]	WAVT/WPPA	FM/AM	180'/180'	Positive	No	None
Sunbury	WKOK	AM/FM	310/300'	Positive	No	PARAN
Williamsport	WILQ/WLYC	FM/AM	220'	Positive	No	Joint Venture

Notes:

1. Not viable candidate because station building new tower before this program can be implemented. Also lacks space for adequate radial system. PARAN may be feasible later if this location is needed.
2. Not good candidate because antenna site is very hilly and in a mountainous area which would require extensive modifications and testing to determine its suitability.

3.9.7 Additional Survey Requirements

A preliminary analysis has selected candidate stations for future surveys in each prospective transmit zone. They are identified in Appendix B. Preliminary survey planning for the remaining 15 zones will be similar to the procedures utilized for Pennsylvania and Texas, which involved reviewing FEMA risk area maps, FCC records, establishing contact by telephone, correspondence and if necessary visits to candidate stations. Upon completion of these actions, full site surveys would be planned for all 17 zones. Section 6 of this report provides a preliminary acquisition plan which includes these surveys.

3.10 PROGRAM D-PRIME ANALYSIS/IMPACTS

Program D-Prime consists of five primary packages which are divided into ten operational program elements. Only the Emergency Broadcast System/Broadcast Station Protection Plan (EBS/BSPP) portion is germane to the present analysis.

Presently, there are about 600 broadcast stations in the BSPP. The goal is 2700. The stations selected for the Low Frequency Mobile Warning System will become part of the BSPP. Accordingly, this system would definitely have an economic impact on Program D-Prime.

Using the Pennsylvania and Texas Surveys as examples, there were only 3 BSPP stations out of the 17 surveyed. Using this as a guide, it can be assumed that:

1. By extrapolation, out of 85 broadcast stations needed for the system, only 15 will be in the BSPP.

2. If the other 70 become BSPP stations by virtue of the fact that they have been selected for the LFMWS, normal Program D-prime funding will be available for them, and they will become part of the already programmed total for the BSPP.

3. New funds needed for the existing 15 BSPP stations and the new 70 BSPP stations will include the incremental costs of larger generators and shelters.

4. Funds required to upgrade the 85 stations, as above in 3, will represent the total cost impact of the LFMWS on Program D-Prime.

These increased costs to Program D-Prime are noted in Section 7, Cost Analysis.

3.11 NAWAS IMPACTS

The present NAWAS is a dedicated voice network of warning and control circuits and switching and control facilities leased from AT&T. Although not a subject of this analysis it would be logical to consider the NAWAS a candidate, together with alternatives for survivability, for the long haul system required to interconnect the National Warning Centers with the LF units . On the other hand, a full time reliable LF coverage of the entire continental USA would render many NAWAS drops redundant and therefore unnecessary. If the LF warning system were approved and implemented, the NAWAS could be modified, resulting in the elimination of many circuits to state and local warning points, but retained as a basic long-haul interconnect, as above, backed up by a survivable long-haul radio system.

3.12 DUAL USE FOR EMERGENCIES

As noted earlier in this section the LFMWS has the additional capability of providing broadcast warning to specific areas threatened by impending catastrophic events such as severe weather, floods, volcanic activity, earth movements and radiological emergencies. Its signal will blanket areas of lower, but still significant population, which may, under adverse conditions, not receive regular broadcast, FM, TV or weather radio services. Possessing an inherent degree of mobility and flexibility MUs may move to the nearest tower stations to an affected area, once an emergency situation exists, and provide recovery coordination information to authorities within the area. If

tower stations are actually within a stricken area, the MU, with its long haul capability, may relay information out, or may broadcast information to the outside via LF transmission.

SECTION 4 - SYSTEM DESIGN FACTORS

4.1 TECHNOLOGY REVIEW

The most important aspect of this system from a technological point of view is the antenna arrangement. The concept requires utilization of antenna structures which have not been originally designed for the service proposed. In most cases, the available antennas will be too short for the frequencies involved. They will have to be modified to provide a high enough radiation efficiency and bandwidth to produce the required field intensity and intelligence transfer capability. In addition, the current limits of economical loading devices and the voltage breakdown of capacitors, insulators, and the air itself must not be exceeded. There is no aspect of this system concept, other than the antenna system design, which is not straightforward, off-the-shelf technology. Transmitters, receivers, power plants, transporters, shelters, etc., are all standard items, or can be built using off-the-shelf designs and components. For this reason the antenna problem is emphasized in this review. However transmitters, receivers and EMP protection are also covered.

4.1.1 Antennas

The Phase I Study report established guidelines for the use of vertical antennas 350 to 700 feet (142 to 213 meters) in height. The analysis supporting these guidelines was based on propagation requirements and system bandwidth for reasonable cost.

4.1.1.1 Series Fed Vertical Radiators

Towers of this type in this approximate height range have been further analyzed with regard to limitations imposed by peak voltages appearing at the feed point. In Table 4-1, approximations of bandwidth, resistance, antenna current, impedance, capacitive reactance, average and peak voltage are given for various tower electrical heights and thicknesses. Peak voltage should be limited to a maximum of about 50 KV. From the table, then, feasible arrangements are summarized below:

Table 4-1. Vertical Antenna Physical and Electrical Characteristics

PHYSICAL RADIATOR HEIGHT		ASSUMED ELECTRICAL RADIATOR HEIGHT				RADIATOR THICKNESS		BW_{os}	E_{rf}	R_b	I	Z_o	X_a	E_{avr}	E_{peak}
FEET	(METERS)	FEET	METERS	λ	DEGREES	FEET	(METERS)	kHz	PCT	OHMS	AMPERES*	OHMS	-jOHMS	KV*	KV
285	(86.86)	300	(91.44)	.049	17.6	2.7	(0.82)	1.55	46	0.99	159/225	306	965	153/217	216/306
285	(86.86)	300	(91.44)	.049	17.6	18.0	(5.5)	2.47	46	0.99	159/225	192	605	96/136	136/192
***285	(86.86)	390	(118.87)	.063	22.8	18.0	(5.5)	4.39	55	1.67	122/173	192	457	56/79	79/111
380	(115.82)	400	(121.9)	.065	23.4	3.5	(1.07)	2.68	56	1.76	119/169	307	709	84/119	119/168
380	(115.82)	400	(121.9)	.065	23.4	20.0	(6.1)	4.05	56	1.76	119.169	203	469	56/79	79/111
***380	(115.82)	520	(158.5)	.085	30.4	20.0	(6.1)	6.86	67	2.96	92/130	219	373	34/48	48/68
475	(144.75)	500	(152.4)	.081	29.3	4.0	(1.22)	4.10	65	2.75	95/135	313	558	53/75	75/105
**475	(144.75)	500	(152.4)	.081	29.3	20.0	(6.1)	5.94	65	2.75	95/135	216	385	37/52	52/73
***475	(144.75)	618	(188.39)	.100	36.2	20.0	(6.1)	11.16	70	4.20	77/109	229	313	24/34	34/48
570	(173.73)	600	(182.9)	.098	35.1	4.0	(1.22)	6.03	72	3.95	80/113	324	461	37/52	52/73
570	(173.73)	600	(182.9)	.098	35.1	20.0	(6.1)	8.61	72	3.95	80/113	227	323	26/36	36/51
665	(202.71)	700	(213.3)	.114	41.0	5.0	(1.52)	9.37	76	5.39	68.96	320	368	25/35	35/50
760	(231.59(	800	(243.8)	.130	46.8	5.0	(1.52)	12.98	80	7.02	60/84	328	308	18/26	26/37

*Average Power to Antenna = 25/50 KW (SSB)

**See Sample Calculations - Appendix D

***Includes Umbrella Top Load

Note: Single Tower Series Fed - Radials Equal Physical Tower Height
Values for Voltage and Current are for 25/50KW Power (Avg.) to the Antenna

f = 160 kHz

λ = 6150 feet (1874 meters)

Physical Tower Height in Feet (Meters)	Modification Proposed: Increase Cross Section	Top Loading	None
380-475 (116-145)	X	X	
475-570 (145-174)	X		
570-760 (174-232)			X

Such arrangements will limit the peak voltage to 50 kV for a 50 kW PEP output to the antenna. At the same time, the system bandwidth will be 4 kHz or better at the lowest frequency of 160 kHz which is a worst case for the operating band of 160 kHz to 190 kHz.

By limiting the power to the antenna to 50 kW PEP and adhering to the tower configurations indicated in Table 4-1 which provide for 50 kV peak or less, it will not be necessary to take expensive action designed to reduce voltage breakdown effects, such as the use of larger conductors, corona rings, special insulators, etc. A higher power level, without such sophisticated countermeasures would increase the danger of air breakdown, resulting in the formation of plumes and corona.

Because of the effect that modifications to the tower will have on the propagation pattern of the normal MF broadcast, as well as the effect on the structural integrity of the tower, this approach must be viewed with extreme caution. MF broadcast towers of this type in the 570-760 foot (174-232 meter) class, not requiring structural modification for LF diplexing, should be used where available.

4.1.1.2 Shunt Fed Vertical Radiators

Table 4-1 also applies in general to grounded towers of equivalent heights and diameters. What is different is how the transmission line to the tower is matched to the radiating structure for efficient power transfer from the transmitter. Various methods of shunt feeding towers are utilized including:

1. A sloping wire to a point somewhere up the tower above ground

2. A wire up the center of the tower to a suitable tap point
3. A short folded unipole
4. A gamma match.

Methods 3 and 4 shunt all or part of a grounded tower to provide an impedance match at the bottom fed point and since the fed portion parallels the grounded member, transmission line theory applies, for impedance transformation.

In all four cases top loading and diameter enhancement would have to be used. In addition, guy wires would have to be insulated and a proper radial system provided. For towers as configured in Table 4-1, the complex base impedance will be approximately as indicated in the R_b and X_a columns. Upon this will depend the kind of shunt feed that will work. The only way to use methods 1 and 2 above is for the tower to approach an electrical 90 degrees ($\lambda/4$) in height. To realize this, in the LF band, such a tower would have a physical height of about 1000 feet (305 meters) and have a large umbrella type top load. Applying this kind of modification to existing grounded towers in this height class is impractical.

The short folded unipole approach (Method 3) will provide for a step up in impedance; but, because of the fact that the tower will not approach a $\lambda/4$ electrical height, the load will still appear reactive. If the tap point of the feed wires to the tower can be adjusted so that the resistive component is approximately 50 ohms, then a simple capacitive coupling between the coaxial cable and unipole can be achieved. However, for the required range of frequencies, it would require an 850 to 1000 foot (259-305 meter) tower, or a short wider tower, with a large umbrella type top load, which is also impractical. Even with the folded unipole approach, a tuning unit would have to be provided to match the folded unipole feed to the coaxial transmission line by tuning out capacitive reactance and providing the required resistive load.

The Gamma Match (Method 4) is a version of a folded unipole, except that instead of a cage of wires around the tower, a parallel tower or cage of wires separated a number of feet from the grounded tower forms a transmission line up to the tap point on the main tower. The ratio of diameters of the main tower and the feed tower (or wire cage), and the ratio of the spacing between the two towers and the main tower diameter, can be adjusted to achieve an impedance step up at the tower base, where a coaxial line can be matched to the structure through an impedance transformation network.

4.1.1.3 Multiple Tuned Antennas

The most successful method of improving LF antenna radiation efficiency is that of multiple tuning. Therefore, this should be considered for application.

The folded unipole arrangement mentioned above is a configuration which might be arranged for multiple feed and tuning as a means of increasing feed point resistance. Another configuration utilizing this principle is the PARAN antenna marketed by Continental Electronics of Dallas, Texas.

4.1.1.3.1 Short Folded Unipole

If the folded unipole previously discussed consists of a central insulated tower and a cage of wires around it, feeding of some of the wires and tuning the others and the tower to ground may be accomplished. This will provide for a step up of the feed point impedance and will allow for matching the transmission line using a T or L network.

4.1.1.3.2 The PARAN*

PARAN stands for "Perimeter Array Antenna". Because of its configuration and the way it is fed and tuned, it has a high radiation efficiency, is broad-band and can be used with a

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*"A Short Broadcast Antenna for Restricted Height Locations", Homer A. Ray, Continental Electronics Manufacturing Company, Dallas, Texas.

vertical dimension less than one-fifth of the height of a single vertical quarterwave antenna. This means that a PARAN could be built for use on 160 kHz with a height of 200 feet (61 meters), utilizing four towers in a 200 foot (61 meters) square with a large top-load strung between them. The radiating structure can be envisioned as a very wide cylinder with the four towers embedded on its periphery. Ideally, a radial system within the square and extending outward for about 600 feet (183 meters) would be required.

At a 11 February 1980 meeting in Dallas, the proposed concept of how the PARAN antenna could help this project by providing an additional antenna alternative was reviewed. The design of a PARAN for 160 kHz use with the following characteristics was proposed:

Number of Towers = 4	Tower Height: 200 Ft. (61 meters)
R_a + Coils + ground = 8.0Ω	(11.7°)
X_a: 400Ω I_a: 39 amps	R_e = 87%
Bandwidth (3dB) = 3.2 kHz	E_a: 15 KV

The Continental Electronics Mfg. Co. was asked to provide a cost estimate covering materials for this antenna. Their estimate is included in Section 7.

The Dallas engineers did not see any objection to building a PARAN around an existing tower at its electrical center which would be insulated from and help support the PARAN top load, and use a common (but extended) radial system. The Dallas engineers did, however, express concern about extra loads under wind and ice conditions with regard to the PARAN top load. This may be compensated for by putting counter-weights at the four PARAN towers so that under icing conditions the top load can sag instead of breaking or placing undue stresses on its tower supports.

Since no actual test data is available on this antenna in this application, arrangements should be made to build and test a prototype.

4.1.2 Transmitters

A number of manufacturers are in a position to quote SSB transmitters in the 50-100 kW PEP class which use vacuum tubes of the high gain tetrode type operating in class AB1, linear. Since the LFMWS will be operating in the SSB mode (upper sideband) with a carrier suppressed greater than 40 DB (A3J), a transmitter with an average power output in one 3 kHz sideband of 25 kW will provide the same service to listeners who have appropriate receiving equipment as a DSB AM (A3) transmitter with a 50 kW carrier modulated 100 percent.

Since current plans are to operate on a maximum or 10 spot frequencies in the 160-190 kHz band, there is no need to provide for synthesizers. Rather, the transmitters can be crystal controlled--providing a savings--and can be much smaller and less expensive than 50 kW DSB-AM transmitters. In addition, voltages throughout the antenna system will be lower, and, hence, insulation requirements will be greatly reduced.

There is some question as to whether a fully solid state transmitter operating at these power levels can achieve the required degree of linearity in the high powered output stages; However, fully solid state should not be ruled out, if vendors are willing to guarantee linearity to meet required specifications. Linearity will not be of prime importance since only single channel operation is contemplated and high fidelity sound transmission is not a requirement. However, harmonic interference to other services could result from non-linear operation. It would be preferable to avoid the use of expensive harmonic line filters, if possible.

4.1.3 Receivers

The design objective should be for a receiver capable of being used by unskilled personnel for reception of upper sideband transmissions in the 160-190 kHz portion of the LF band. The receiver should have good selectivity with a bandwidth of about 2.5 kHz to the -3 dB points, but it does not need to have very good sensitivity or noise performance due to the high signal levels of 100 μV/meter or more and the masking effect that the high atmospheric and cosmic noise level in this frequency range will have over the white noise contribution of the receiver front end. Low cost is a prime consideration. A suitable receiver would be similar in configuration to that depicted in Figure 4-1.

It is proposed that each receiver have a number of crystal positions (say, 3) which may be switched for spot-frequency selection, with a clarifier circuit so that any frequency drift of the transmitter or receiver can be compensated for by the adjustment of a single knob, in order to provide for clear, natural voice reception. The limits of fine frequency tuning provided by the clarifier circuit can be $\pm$300 Hz. If double conversion is used, this fine tuning can be applied by causing the required amount of frequency shift in the second conversion oscillator circuit. The simplified clarifier circuit shown in Figure 4-2 does this in linear fashion by using a linear wire wound potentionmeter to pull two oscillators with a difference frequency of 1.1 mHz in opposite directions by variable capacitance diodes.

After passing through a crystal filter and amplification, signals are detected by a product detector, the carrier being reinserted by a local LF crystal oscillator. Muting and A.G.C. circuits are utilized.

A receiver similar to that described above has been designed and built for MF SSB use in the Merchant Marine community (Figures 4-1 and 4-2). It is felt that the development of integrated circuit technology over the past few years will allow the use of

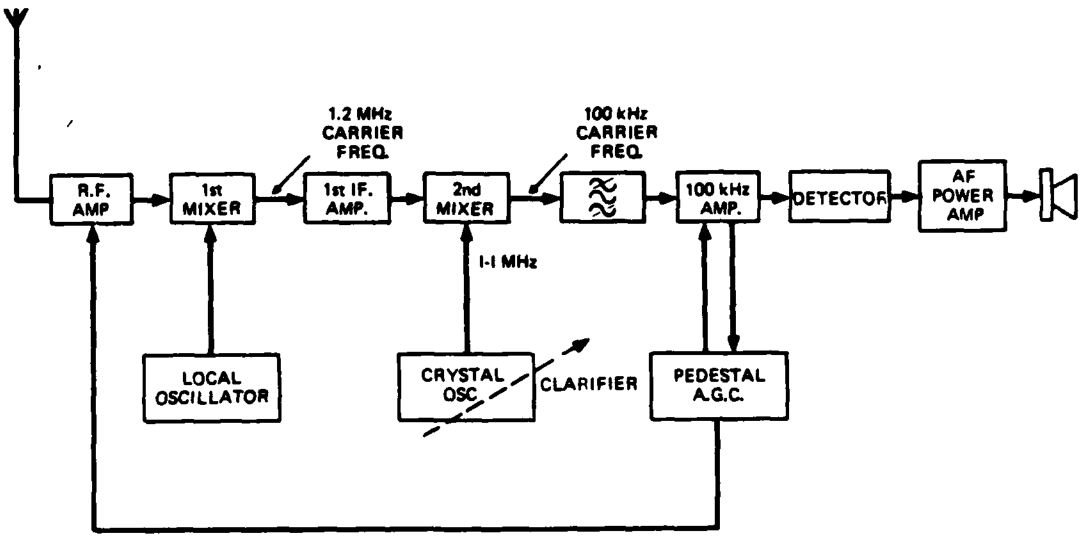


Figure 4-1. Simplified Block Schematic of SSB Receiver

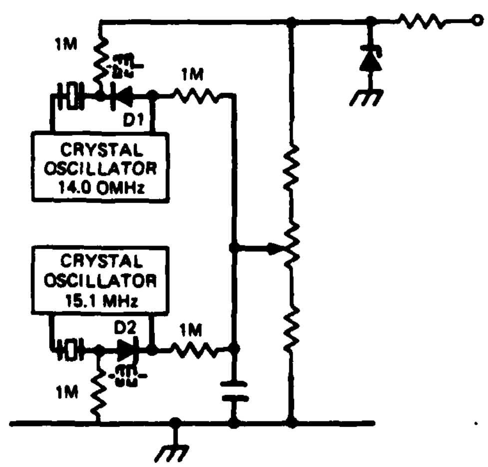


Figure 4-2. Clarifier Tuning Arrangement

such circuits rather than discrete components, to considerably reduce the cost and enhance the reliability of the receivers needed for the LF warning function.

4.2 PROPAGATION ANALYSIS

As has been discussed previously, propagation of the ground wave is greatly dependent on ground conductivity. The radiation efficiency of a vertical antenna, close to ground, can be increased if a system of radial wires fans out from the tower base and is buried just below the ground surface. The Phase I Study report indicated that radials should ideally be $\lambda/4$ for the lowest frequency utilized. This means that radials for the frequency band of 160 kHz through 190 kHz would have to be between 1538 and 1295 feet (466.8 and 394.7 meters), or approximately one-quarter mile in length. Only in rare cases will sufficient land be available around existing towers, and free of development plans, to allow this. With AM MF towers in the 350 to 700 foot (142 to 213 meter) range, analysis shows that radials are usually installed equal to one tower height. This means that for the frequency range these radials would be $\lambda/20$ to $\lambda/8$ in length. Throughout the Phase I Study $\lambda/4$ radials were assumed in calculating field intensity and bandwidth. In a practical sense it will not be possible to realize $\lambda/4$ radials. This must be considered for its impact on the field intensity and in turn on number of transmit zones required.

4.2.1 Field Intensity

Reduction of radial length from $\lambda/4$ to $\lambda/20$ would reduce the distance to the 500 μV/meter contour by about 14 percent. This is a worst case for 160 kHz with a 300 foot (91.44 meter) tower and 300 foot (91.44 meter) radials. For higher frequencies with elecrically higher towers (electrically longer radials) at LF the reduction will be less. At 190 kHz with 700 foot (213 meter) radials ($\lambda/8$) for example, the distance to the 500 μV/meter contour would only be reduced by about 7 percent below that with $\lambda/4$ radials.

The field intensity contours of the Phase I study were predicated on 50 kW average carrier power to the antenna. Everyone within the 500 μV/meter contour produced by this carrier should be assured of intelligible reception of AM DSB (A3) radio telephone signals for 90 percent of the time during maximum periods of atmospheric and cosmic noise. Such radiotelephone signals are of a nominal 6 kHz bandwidth, and each sideband, under conditions of 100 percent modulation, contains an average power of 12.5 kW.

Use of SSB, suppressed carrier emission (A3J) is proposed, rather than DSB (A3). The transmitter to be utilized will be rated at 50 kW PEP output. The average power output with single test tone sinewave modulation transmitted in a single 3 kHz sideband (with suppressed carrier) producing 50 kW PEP output will be 25 kW. (The power allocated to the suppressed carrier will be not more than 2.5 watts and hence insignificant to this discussion.) This represents a 3 dB improvement in sideband modulation power per unit of bandwidth over the DSB case. The 500 μV/meter contour plot based upon the 50 kW carrier now becomes a 355 μV/meter contour for the 25 kW SSB tone. (Reduction in power of 2 to 1 represents a field intensity reduction of 1.41 to 1). Since the system is utilizing only half of the bandwidth in the SSB case as compared to the DSB case, the 355 μV/meter contour should be sufficient for SSB reception 90 percent of the time during periods of maximum atmospheric and cosmic noise. This is true since the SSB receiver can work with a total bandwidth (and noise) of only 50 percent that of a DSB receiver (3 kHz vs 6 kHz).

4.2.2 Transmit Zones

Because of the following characteristics of SSB compared to DSB transmission:

a. Reduction in bandwidth,

b. Reduction in possible interference due to cross-modulation between adjacent channel high-level AM carriers,

A significant improvement may be achieved in the capability of spot frequency SSB receivers to detect and demodulate intelligible LF warning signals. Consequently, while having reduced the field intensity at the service zone limit from 500 μV/meter to 355 μV/meter due to the transmitter power reduction from 50 kW to 25 kW, the approximation of 17 warning zones is still valid.

4.3 EQUIPMENT SURVEY

A survey was conducted of several vendors in order to locate off-the-shelf equipment which would satisfy the requirements of the system. This effort involved researching state-of-the-art techniques versus hardware manufacturers to ensure that the most reliable and economical equipment was identified which would support the LFMWS.

Table 4-2 is an equipment and manufacturer cross matrix which lists the types of equipment and the vendors who can supply it. It is intended to be utilized only as a basic guide because most of the vendors can overlap into several of the equipment areas, and there are many more manufacturers who could supply similar equipment.

4.4 EMP PROTECTION

4.4.1 General

EMP refers to the electromagnetic disturbance of the environment which accompanies a nuclear weapon detonation. The fundamental mechanism of EMP generation involves transformation of energy released in the form of photons into the radio frequency electromagnetic spectrum via several intermediate steps. These photons interact with the atmosphere in the "source region", creating

Table 4-2. LF System Equipment and Manufacturer Cross Reference

	REPRESENTATIVE VENDORS																							
EQUIPMENT	ADVANCE INDUSTRIES, INC.	ANTENNA PRODUCTS CO.	CATERPILLAR	* CINCINNATI ELEX	CODEX	* CONTINENTAL ELEX	* DECCA-AUSTIN INSULATOR	* ELEX RESEARCH CORP.	FT. WORTH TOWER CO. INC.	FRED A. NUDD CORP.	GRASIS CORPORATION	* HARRIS CORP.	* HF COMM	KOHLER	* MULTRONICS	NORTHROP/PAGE	PRITCHARD-KING	* ROCKWELL INTL.	* SCIENTIFIC RADIO SYS.	* STAINLESS TOWERS	TRW	* TTY CORP.	* UNARCO-ROHN	* WESTINGHOUSE
ANTENNA TOWERS	X	X				X			X	X	X	X				X				X			X	
COUPLERS		X				X						X			X	X			X					
DIPLEXERS		X				X									X									
FOLDED UNIPOLE KITS		X													X					X			X	
GUYING	X	X				X	X		X	X	X	X				X				X			X	
MAG TAPE RECORDERS												X												
MOTOR GENERATORS			X									X		X										
PARAN ANTENNAS						X																		
RADIALS SYSTEM						X																	X	
RECEIVERS				X				X				X	X			X		X	X					X
SHELTERS (COMM)	X					X			X			X				X	X							
TTYS												X										X		
TOP LOADS		X				X														X			X	X
TRANSMITTERS						X						X				X		X	X					
MODEMS					X																X			

*Provided Oral or Written Budgetary Estimates

moving charges which radiate electromagnetic energy providing that some asymmetry exists. Figure 4-3 illustrates the process for two burst point locations.

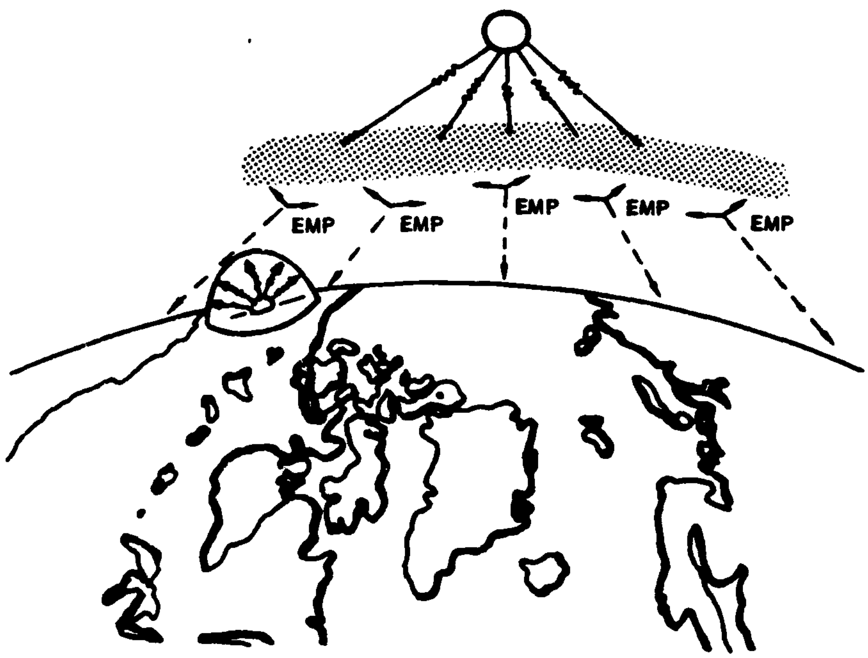


Figure 4-3. Near-Surface and Exoatmospheric EMP Sources

In the case of a near-surface burst, an intense EMP is created in a localized region and it is accompanied by other weapons effects including blast, heat, radiation, and debris. This kind of an event might effect one LFMWS tower station but the system would survive.

Because the interaction path length is large in the upper atmosphere, a burst above this altitude creates a source region of massive extent. Presence of the geomagnetic field causes asymmetrical current flow, efficiently converting energy into a downward traveling EMP wave over a significant fraction of the earth's surface. Because the range from the source to a surface observer is large, high altitude EMP is not accompanied by other

prompt nuclear effects of magnitude for concern. High altitude EMP is a primary threat to all communications networks and their equipment.

The high altitude EMP wave induces charges and currents on conducting materials at the surface and transients as large as thousands of amperes and hundreds of kilovolts may be experienced. The following is a discussion of approaches to protect the operational capabilities of the LFMWS in view of the potential for equipment damage presented by EMP.

4.4.2 Threat Characteristics

The original form of the high altitude EMP threat is a plane electromagnetic wave, propagating toward the earth's surface from the upper atmosphere. Because the relative location of the burst, with respect to the facility, cannot be known a priori, a continuum of angles of incidence and polarization must be considered. Typically, electric (E) field magnitudes of tens of kilovolts per meter and pulse widths of the order of a few hundred nanoseconds characterize the predicated threat.

A transient signal may appear at terminals of potentially susceptible equipment depending upon the coupling geometry. Long conductors (buried, on the surface, or elevated), apertures and coupling into cavities, intentional and inadvertant antennas, and coupling through structural and cable shields provide this geometry.

4.4.3 Approaches to Protection

Standard commercial or military electronics equipment would fail with certainty if subjected to transients of the magnitude of worst case EMP responses. Hardening, in the EMP sense, implies increasing equipment robustness to tolerate such signals or circumvent them, attenuating the induced signals to stress levels at which the equipment is inherently survivable or some combination of these actions.

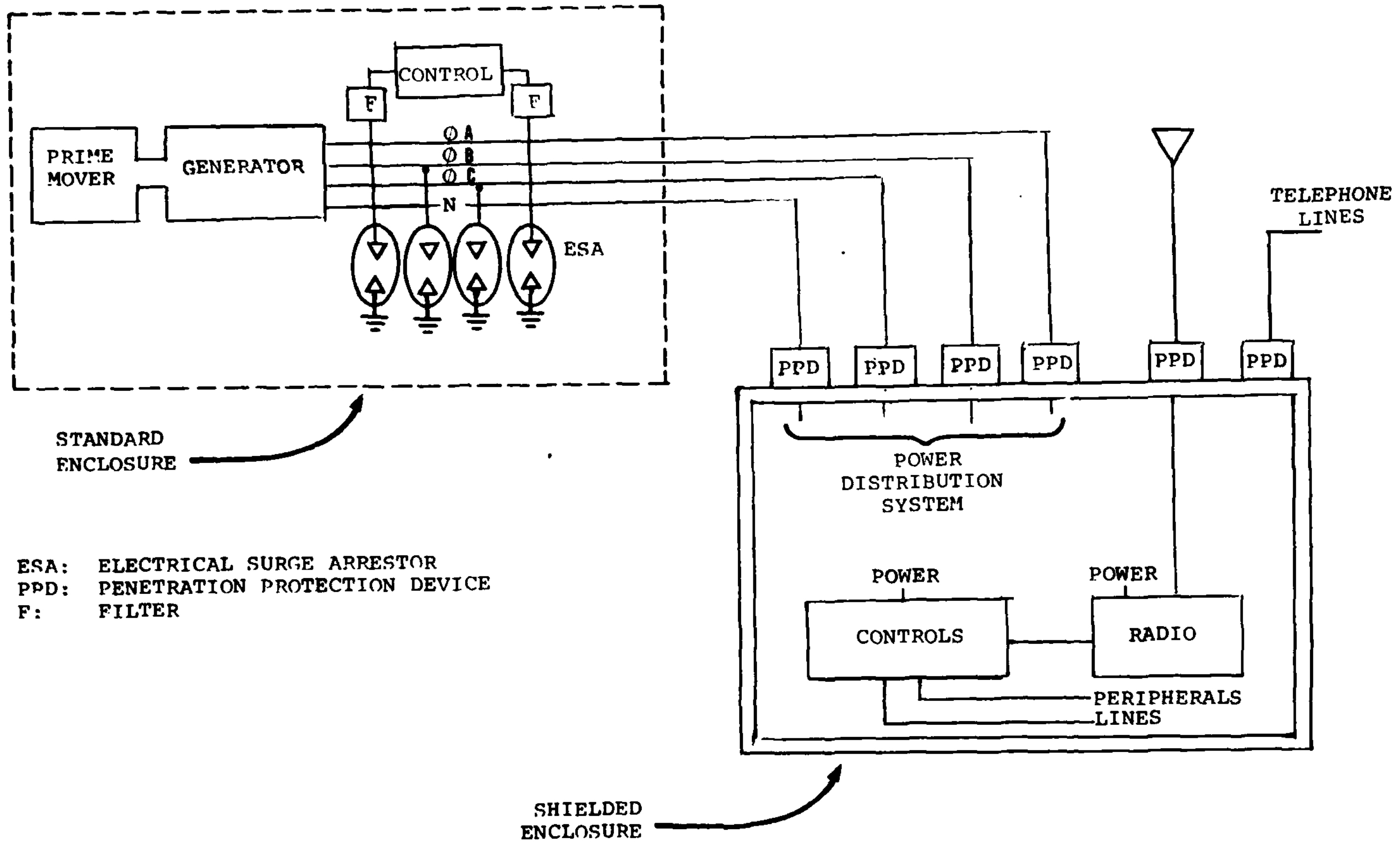
One approach involves creation of a "protected volume" within which equipment can be deployed with little regard for EMP effects. A shield (i.e., a metal enclosure with protected penetrations) forms a topological surface surrounding the equipment performing those functions to be preserved. The quality of the shield is chosen on the basis of equipment class (power, communications, and/or computers), rather than specific circuits and components to be protected. EMP-induced stresses are reduced by the shield to signal levels encountered in normal operation and in designs compatible with neighboring hardware.

The protected volume approach produces high confidence, low maintenance protection and configuration control is generally unnecessary inside the shield. Equipment modifications and additions can be made without significant concern for EMP. Therefore, this type of hardening is ideally suited for highly interconnected equipment complements, large collections of very sensitive components, and locations where the electronics suite may be changing frequently. The critical LFMWS equipment will be housed in such a shield.

Another approach is "box-level hardening" which examines coupling geometries at the specific facility and susceptibilities of the particular circuits and installs those devices at equipment interfaces as needed to maintain adequate margin between stress and failure levels. Potential choices for protection devices include filters, surge suppressors, dielectric links and waveguides, or a volume shield (usually of more limited extent such as a single box or rack) might be implemented. This approach has been applied with success on power generators.

Both the volume shielding and the "black box protection" approaches are expected to be required for hardening of the LFMWS.

A system composed of a power generator, control, and radio equipment can be used to illustrate the EMP hardening. This is depicted in Figure 4-4. It is known from testing experience



ESA: ELECTRICAL SURGE ARRESTOR
PPD: PENETRATION PROTECTION DEVICE
F: FILTER

Figure 4-4. Example of EMP Hardening

that generator/power subsystems will survive the EMP environment if surge arrestors are employed on each of the phases to limit pulse duration. The more sensitive control circuits are mounted in metallic enclosures (not true shields) and will survive if isolated from the power leads by 40-60 dB.

The control and radio equipment, on the other hand, are highly interconnected to sensors and peripherals and are candidates for volume hardening.

References to "state-of-the-art" EMP protective devices in Appendix C are made with the above techniques in mind. Further discussion of EMP protection in great detail is contained in "EMP Protective Systems", TR-61-B, DCPA, Washington, D.C., July 1976.

SECTION 5 - CONCEPT REEVALUATION

5.1 SYSTEM ALTERNATIVES

The low frequency mobile warning system described in the Phase I report provides a concept which is technically feasible but which, as proven by further analysis and survey, might not be practically achievable or economically feasible unless alternatives are devised so that available broadcast facilities meet required system criteria. These criteria as developed in Phase I include:

1. Sufficient number of properly sited locations outside of major risk areas with towers 350-700 feet (142-213 meters) in height
2. Insulation for 50 kW systems
3. Non-interference between systems (LF vs MF)

Technical and operational problems have surfaced which would prevent meeting these criteria, but which can be resolved by devising alternatives either in the technical configuration of the subsystems or in the operational procedures specified. These alternatives are discussed below.

In addition, there is a possible alternative, major in scope, of elimination of MUs in favor of multiple hardened EBS stations with an LF transmission capability. Some consideration and discussion of this possibility is also included.

5.1.1 Technical Alternatives

The criteria may be met by the specification of technical alternatives not included under the Phase I concept.

5.1.1.1 Power Reduction

The first alternative is to reduce the average power output of the LF transmitter from 50 kW to 25 kW. The impact that this has upon the coverage of the system is discussed in Sections 4.1.2, 4.2.1, and 4.2.2. Since peak power from a 50 kW DSB

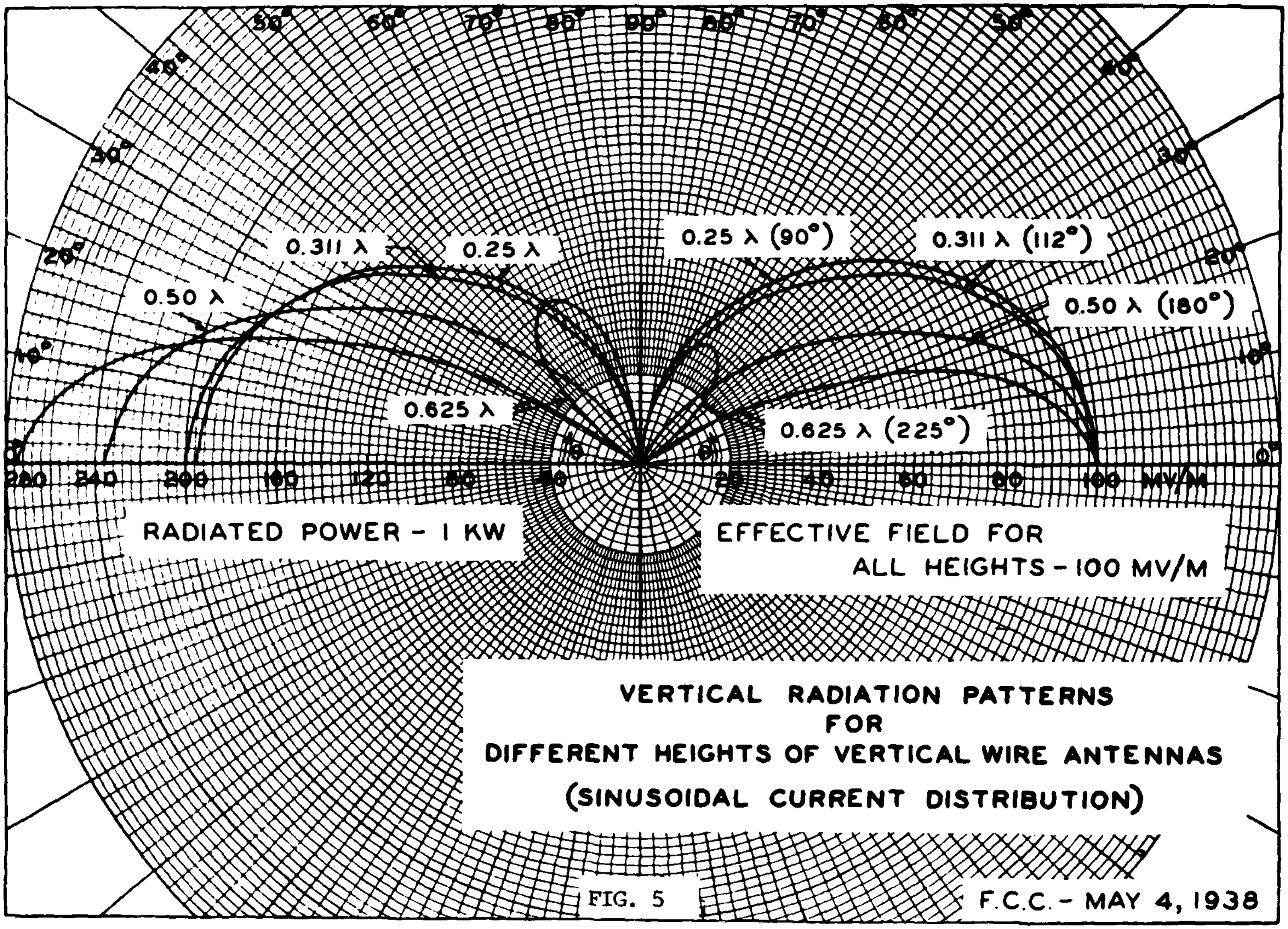
transmitter modulated 100 percent is 200 kW, and peak power from a 25 kW SSB transmitter under similar conditions is 50 kW, it is evident that antenna insulation requirements have been reduced for voltage breakdown by approximately 2 to 1, equivalent to the peak power reduction of 4 to 1, or 6 dB. This provides an alternative of selecting lower powered broadcasters for antenna stations. For example, a broadcast antenna system now insulated for voltages produced by a 10 kW MF transmitter (40 kW peak power) is now within 1 dB in voltage performance of being acceptable for the LF 50 kw peak output, provided it is electrically high enough at LF.

5.1.1.2 Common Antenna Avoidance

With equal peak power to any antenna at two different frequencies, in this case one LF and one MF, the feed point voltages will be quite different at the two frequencies. This is because the antenna will present different impedances at the feed point for the two frequencies. As the MF antenna is modified to increase the resistive component and decrease the reactance to effectively reduce the voltage at LF, its performance can be significantly improved at MF, resulting in a required reduction in MF power as well.

If the MF antenna is a half-wave ($.5\lambda$) for the broadcast frequency, the modification for LF, such as adding a top load, should not increase the MF height to much more than $.625\lambda$, because this is the height beyond which skywave radiation will be enhanced and reduced ground wave will result. This would severely impact the broadcast operation, as indicated in Figure 5-1.

If the MF antenna is a quarter wave ($.25\lambda$) for the broadcast frequency; and this is the more usual situation; then it may be too short for economical modification for LF use, unless the broadcast station is at the low end of the MF band. If the MF antenna is not modified to make it appear like a 500 to 800 foot tower at LF, the voltages appearing at the feed point for LF will far exceed those at MF. In such a case, the insulation may



FCC § 73.190 FIGURE 5

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Figure 5-1. Vertical Antenna Radiation.

require extensive modification. It is apparent that the broadcast towers that will meet requirements for simultaneous use at LF and MF, even with the reduction in LF power input, will be the exception rather than the rule. In view of this, another alternative is required.

The second alternative is designed to avoid the use of a common antenna but still to reap the advantages of co-siting and using a common ground radial system. This is done by erecting a short LF multi-tower antenna around the MF antenna, connecting it to the MF radial system and extending these radials if possible. This alternative is made possible by using the PARAN type antenna discussed in Section 4.1.1.3.2. This antenna is under a U.S. Government patent. Figure 5-2 is a photograph of a small PARAN 50 feet high for MF broadcasting. Since the MF and LF antennas installed in this manner are electrically symmetrical with respect to each other, and would be mutually detuned (harmonically related MF/LF frequencies are to be avoided), radiation pattern distortion of one by the other should be insignificant. This alternative not only removes the voltage and insulation problem, but it expands the field of candidate broadcast station antennas by removing the broadcast station power output as a major factor. This, in turn, increases the chances of finding broadcast stations suitably located outside of high risk areas. It also expands the LFMWS candidate field to those broadcast stations using in-line tower arrays in which the center tower is used daytime and all towers are used at night. It reduces the required broadcast station tower height to about 240 feet. The PARAN for the LF application is 200 feet high and the broadcast tower at the center should be the higher for two basic reasons:

1. The center broadcast tower will help support the PARAN top load.

2. The broadcaster may have program circuit microwave/UHF or FM/TV antennas mounted near the top of his AM tower.

Acceptable configurations of LF-PARAN (0) towers and MF(X) broadcast towers are shown below in Figures 5-3, 5-4, and 5-5.

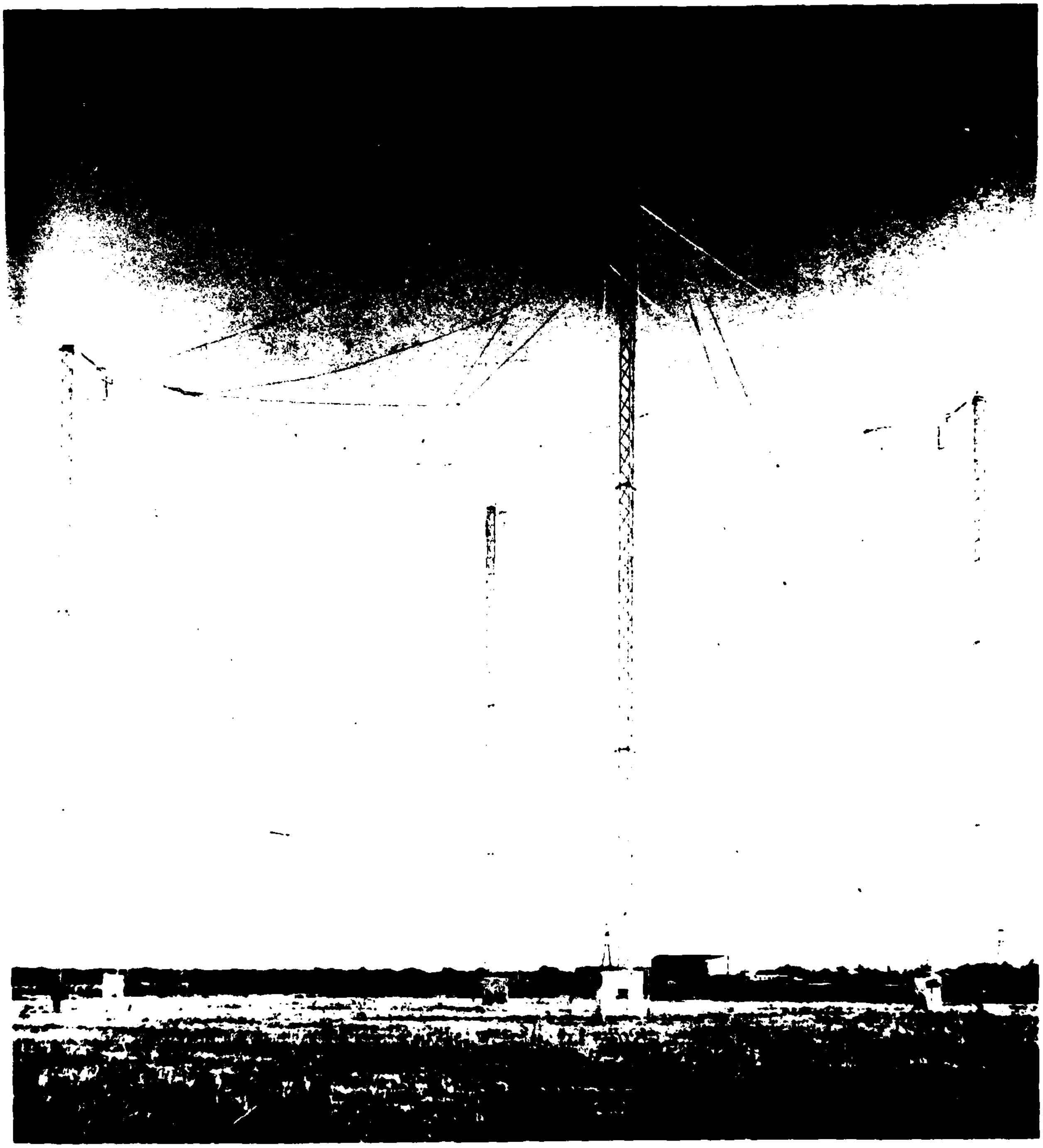

Figure 5-2. PARAN Broadcast Antenna

```
        o     o
           x
        o     o
```

Figure 5-3. PARAN with Single Broadcast Tower

```
        o     o
  x        x        x
        o     o
```

Figure 5-4. PARAN with Three Element Broadcast Array

```
              o     o
  x      x       x       x      x
              o     o
```

Figure 5-5. PARAN with Five Element Broadcast Array

In all cases, the LF towers are shorter than the MF towers. Although they are in the near field of the MF antennas, interaction theory indicates that no parasitic reradiation problem should exist. In addition, they are detuned and harmonic frequencies are avoided by frequency management.

5.1.1.3 Broadcast Station Relocation

As a result the field survey activity described in Paragraph 3.9, a third technical alternative was identified. During the Phase I study effort, there was nothing to indicate the fairly large percentage of candidate broadcast stations which have plans to relocate and upgrade their transmission plant. Of seventeen stations surveyed, eight had such plans. Since this would make planning for cooperative operation, tower/antenna modifications, shelter construction, and power plant installation at their existing facilities futile, the idea of a joint venture was proposed. The scheme involves the preparation of a detailed upgrade plan and schedule by the broadcaster, together with a cost estimate. This is then reviewed, the new site surveyed, and possibly ground conductivity measurements and LF propagation tests conducted by the Government. The Government then specifies the additions or modifications to the broadcaster's plan to accommodate the LF warning system, and an incremental cost estimate is prepared. After agreement to the plan, the broadcaster would be responsible for the costs for his original plan and the Government responsible for the incremental costs. Consultants for both sides monitor and control the actual implementation process. Admittedly there would be scheduling and funding problems, as well as many other related details not addressed in this discussion. However, this situation can be considered a viable alternative for implementation of the LFMWS.

An example, to be used as a basis for the evaluation of this alternative, would be the Stephenville, Texas candidate (KSTV/KWWM). The station will shortly move the FM transmitter to a new 20 acre site and construct an 800 foot tower. At the present time both the AM and FM transmitters use the same 200 foot tower which is located in a congested suburban area, severely restricting radial extension or any new construction. The present station location could not be a candidate; however, through the medium of a joint venture, as described above, this station at its new location is a prime candidate for the program.

When the new 800 foot tower is erected, it would be made strong enough to support an umbrella type top-load, and would be provided with a suitable base insulator, insulated guys, and a radial system. Under these conditions, the tower will approach an electrical height of 80 degrees for the LF system. Since the property is large, a very good radial system could be installed. The actual details would depend on design engineering to be performed as part of the joint plan mentioned above.

The costs for the antenna system, over and above the costs for providing and erecting a basic grounded 800 foot support tower for the FM antenna, would be for the account of the Government.

5.1.2 Operational Alternatives

The criteria may also be met by operational alternatives.

5.1.2.1 Frequency Allocation

The Phase I analysis proposed a frequency allocation plan of ten 3 kHz channels stacked in the 160-190 kHz band as follows:

Channel	kHz
1	160-163
2	163-166
3	166-169
4	169-172
5	172-175
6	175-178
7	178-181
8	181-184
9	184-187
10	187-190

Furthermore, Phase I proposed that Channels 1 through 8 be operational channels with 9 and 10 reserved for spare or coordination channels.

Reference is made to the sensitivity analysis of Phase I which indicates that a change in frequency of 30 kHz can increase coverage between 10 and 23 percent depending on location and variations in ground conductivity. An additional variable to be considered is the increased electrical height and radiation efficiency of the antenna if the frequency is increased. The first operational alternative involves amendment of the frequency allocation plan of Phase I. It is recommended that Channels 3 through 10 be the operational channels, and Channels 1 and 2 be reserved for spare and coordination channels. This plan with channels assigned to zone centers is illustrated in Figure 5-6.

5.1.2.2 Operational Procedures

A second alternative modifies the concept of having two transportable LF facilities, one continuously transmitting and the other moving between multiple towers in each zone. The alternative designates a main base station in each zone, which may be the optimum tower available, and may be on the fringe or even within a high risk area. It will serve as the main station during non-crisis times, and will transmit continuously during these times, except for training missions of the second transportable to other towers within the zone on a periodic basis. As described in

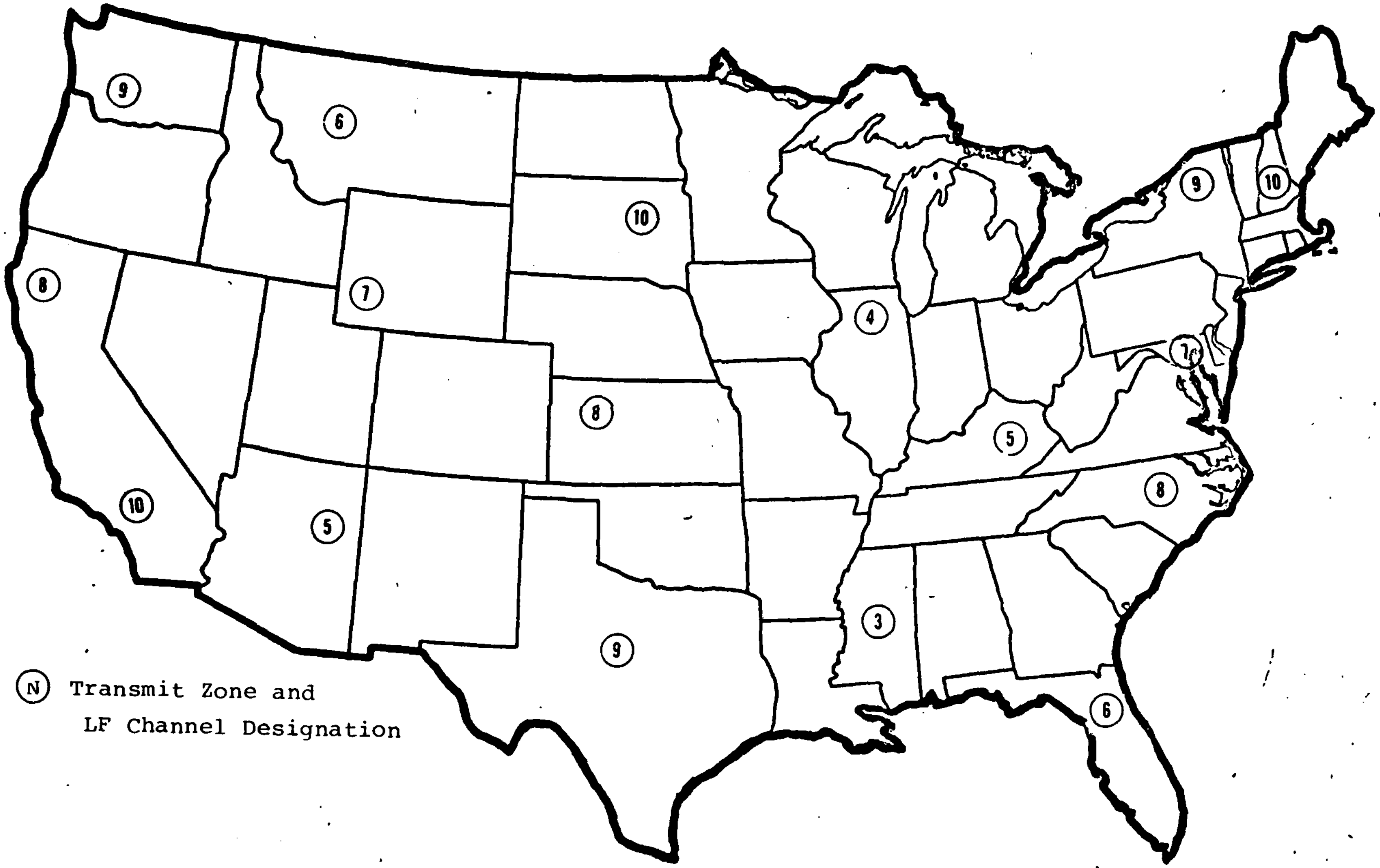

Figure 5-6. Revised Channel Allocation For 8 Channels and 17 Transmit Zones.

Paragraphs 3.2 through 3.6, this provides certain advantages and the procedure can easily revert to the original concept when crisis periods begin to build up.

As an example of this, the optimum and major base station in the Texas Zone Center could be WBAP, on the southern fringe of the Ft. Worth/Dallas high risk area. Both transportables could be based here with one departing periodically on training missions to low-risk area towers and the two crews alternating. The crews can live at home in the metropolitan area except for training mission periods. Upon the onset of actual crisis buildup both transportables and crews would go on a full time field mission footing and return to the less mobile plan at the end of the crisis period.

As another slightly modified example, the existing DIDS station at Edgewood can function as the main base station for Zone 2 (See Figure 5-7) and also as a national training center for transportable crews. In this case, the permanent DIDS facility would be modified for SSB transmission. One transportable would also be based there and be capable of substituting for the permanent facility. The other transportable could be based and supported at a major station in Central Pennsylvania such as Sunbury. Upon onset of a crisis build up, the Edgewood transportable would relocate from the Edgewood location and support its partner in the low risk Central Pennsylvania area. Note that the DIDS transmitter could do this because of its expanded coverage. This provides a triple redundant facility for the important east coast megalopolis.

5.1.2.3 Long Haul Communications

A third operational alternative should be considered. The Phase I analysis assumed the existence of long haul digital warning circuits from the NWC to the LFMWS units. Each transportable had to be equipped to receive this warning information, or command, and translate it into action resulting in an LF warning broadcast over its zone. The long haul circuit could be--as examples--adaptive HF, meteor burst scatter, or LF

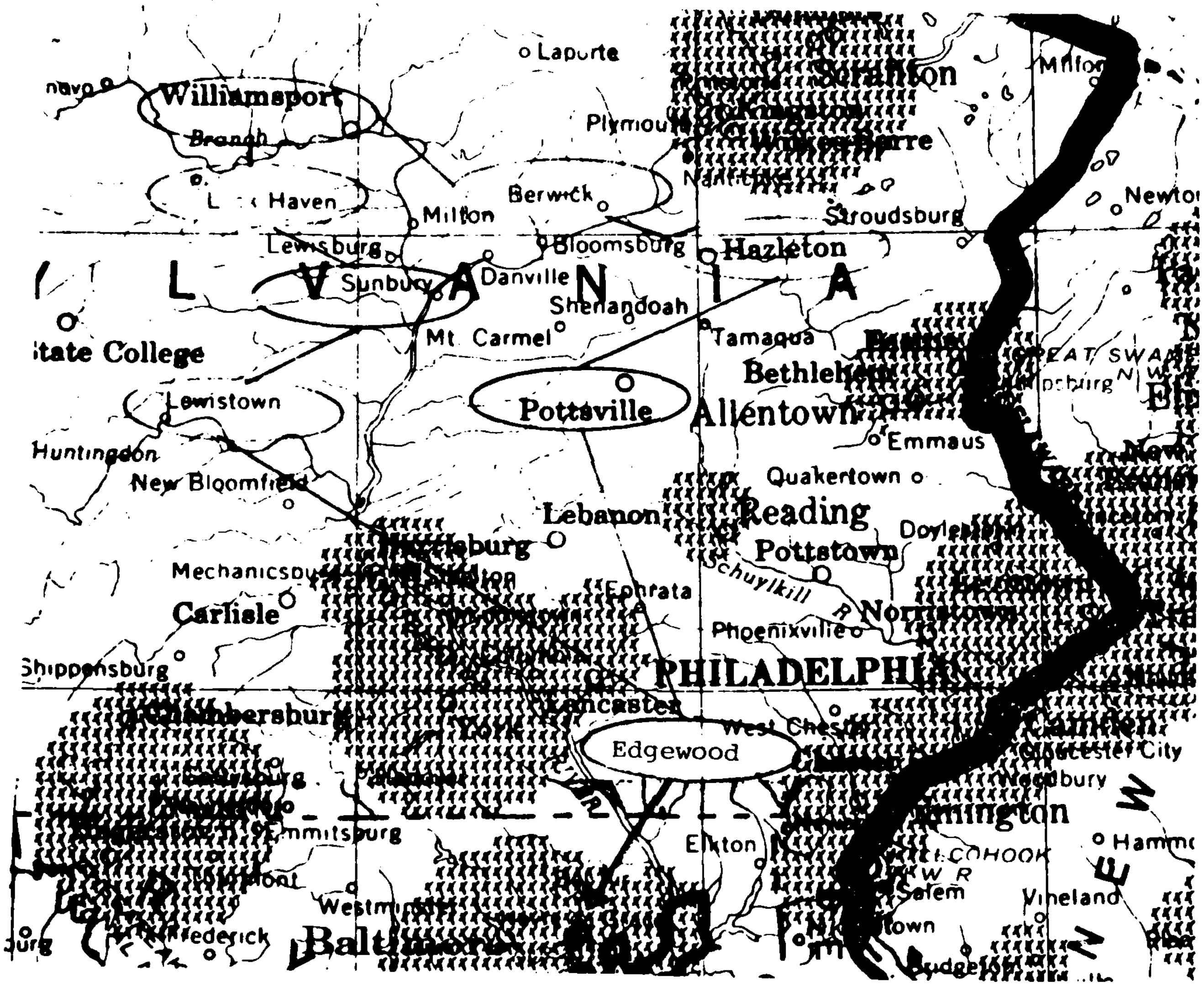

Figure 5-7. Transmit Zone 2 With Edgewood.

relay. In the latter case, the relay is from LF transportable via additional LF relays to LF transportable until all zone centers have received the message or command. Only in this latter case does the LF SSB transmitter have a digital data reception and demodulation capability. If the LF transportable needs a digital data transmission capability, then the transmitter must be able to radiate an average power of up to 25 kW continuously, using FSK tones in the sideband for the period necessary to relay the message and receive an acknowledgement of receipt.

It would be desirable to avoid the need for LFMWS units to operate in any mode other than voice transmission of warning messages to their primary zonal areas promptly upon receipt of the command to do so from the NWC or the ANWC. This would eliminate the need to change from the A3J transmission mode to the FSK mode and back again, a complex intermeshed network operation, and a time consuming and diverting activity at the very time when zonal warnings should be disseminated. Therefore, it is proposed to eliminate, at this time, the requirement for anything but voice transmission (A3J) by the LFMWS transportable stations. The assumption is that the long haul system will either be the normal telephone network, or if that is inoperable, it will be VLF, meteor scatter, or adaptive HF, such that all LFMWS units will receive commands simultaneously and not be involved in a relaying operation.

It may be suggested that if the LFMWS units can receive warnings via a long haul system, then so might the multitude of EOCs, thus, rendering the LFMWS unnecessary. In this regard, it must be pointed out that LF receivers with which the EOC's (and others) will be equipped, will be simple and foolproof. On the other hand, receivers equipped for adaptive communications at HF or VHF for Meteor Burst links will contain microprocessors, use directional antennas, and be comparatively complex to build, operate, and maintain. Therefore these receiving, demodulating, and recording facilities for high speed digital data should be confined to the relatively sophisticated environment of the LFMWS transportables, rather than the EOCs and other warning points.

5.1.2.4 Transporter Configuration

Additional operational analysis has indicated that it would be highly desirable to utilize an equipment shelter which is not an integral part of a truck but removable to allow replacement and repair of the prime mover. While this presents problems involving the design of methods to remove and replace the shelter on its transporter, it appears a worthwhile operational alternative. Not as desirable, but still providing operational advantages, would be a tractor-trailer combination.

5.1.2.5 Operational Mobility

This alternative eliminates only the mobile unit from the basic concept. It involves a trade-off between mobile survivability with lower implementation costs and a higher cost, less survivable fixed system which costs less to operate. It does this by providing every one of the selected 4 to 7 Broadcast stations in each of the 17 transmit zones with a hardened LF transmission capability and the long-haul survivable system to get the warning message to these stations from the National Warning Centers. None of the technical requirements are changed, however, approximately 85 LF and long-haul facilities are now required, permanently installed at stations which are selected in exactly the same way as in the mobile basic concept. One prime station in each transmit zone normally, during non-crisis time, transmits, with the others remaining silent until a crisis occurs; a natural disaster or other emergency dictates the use of a particular alternative station; or, scheduled tests are conducted. Completely eliminated is the need to move large, bulky and high-powered equipment between tower sites and logistically support mobile equipment and the operating crews. Under this alternative, however, over twice as many complete sets of LF and long-haul equipment will be required together with higher costs for spare parts and maintenance. It is presumed that operational and maintenance costs for personnel will be held down by training and

utilizing broadcast station technicians and engineers to operate and maintain the warning facilities installed on their premises. The survivability of this alternative compared to the mobile concept does not improve. There would be over double the number of transmitters and every EBS station with the LF capability would have to be targetted or sabotaged. However, it is conceivable that anyone wishing to destroy the LF warning capability might attempt to disable 85 facilities, if a success factor of 100 percent could be assured. One miss in five per transmit zone would leave the LF capability in a state of survival. The same is true of the basic mobile concept, but in this case one or more MUs per transmit zone could survive an all out effort to disable and with suitable antenna repairs, the mu could function. Furthermore, MUs may move from zone to zone in a contingency, so that the loss of both MUs in one zone could be overcome by the dispatch of an MU from elsewhere, certainly to coordinate survival and recovery operations. In summary the mobile concept would be much less expensive to implement, more expensive to operate and would be the more survivable system.

5.2 ECONOMIC AND COST IMPACTS AND TRADE-OFFS

In the revaluation of the concept deemed technically feasible in Phase I of this task, this study contains a description and analysis of alternatives which have been imposed by actual conditions of availability of suitable broadcast facilities or have resulted from further technical analysis of antenna, propagation, and operational parameters. The alternatives discussed in the preceding section have been adopted if a favorable (PRO) versus unfavorable (CON) balance of impacts prevails. This is detailed in Table 5-1.

5.3 CANDIDATE SYSTEM SPECIFICATION

The draft performance specification included as Appendix C to this report incorporates the alternatives discussed above and shown desirable in Table 5-1. The candidate system for acquisition is as described in the System Description and detailed

in the remainder of Appendix C. The acquisition plan to implement this system is covered in Section 6 of this report. The cost estimate of Section 7 relates to the acquisition plan and the Appendix C specifications.

Table 5-1. Alternatives Evaluation Chart

PHASE I CONCEPT	PHASE II ALTERNATIVE	ALTERNATIVE ECONOMIC/COST IMPACTS
1. 50 kW Transmitter	25 kW Transmitter	PRO: A. Lower transmitter acquisition cost B. Lower antenna acquisition cost C. Smaller/Less costly emergency plant D. Smaller/less costly transporter/shelter E. Lower power consumption F. Reduced environmental control G. Lower spare parts costs CON: A. Possible increase in number of transmit zones pending final surveys and propagation/antenna testing.
2. Diplex on AM Broadcast Tower or Shunt-Feed FM/TV tower	Provide separate but co-sited LF antenna (PARAN) using improved broadcast ground system	PRO: A. Expensive modifications to AM B/C towers not required B. Expensive modifications to FM/TV towers not required C. AM B/C station down-time negligible D. AM B/C station modification application probably not required E. AM B/C station power no longer a constraint. F. LF Station locations optimal G. Higher radiation efficiency of PARAN will increase zone coverage CON: A. Prototype PARAN tests and field intensity measurements required to prove radiation efficiency/performance B. Ditto tests required with concentric AM/BC arrays to prove non-interference between systems C. Cost of PARAN top load deicing arrangement possibly high

Table 5-1. Alternatives Evaluation Chart (Continued)

PHASE I CONCEPT	PHASE II ALTERNATIVE	ALTERNATIVE ECONOMIC/COST IMPACTS
3. Diplex on Existing AM broadcast tower or shunt feed existing FM/TV tower	Participate in joint venture, with B/C stations planning an upgrade move, to provide optimum for both facilities	PRO: A. Expensive modifications to existing AM B/C towers are avoided B. Expensive modifications to existing FM/TV towers are avoided C. B/C station down time or substitute facilities during modifications are avoided D. B/C station pays for consultants and upgrade application to FCC E. AM B/C station power no longer a constraint since new construction can be insulated for higher powered user F. Optimum antenna within cost constraints can be realized for LF user. High radiation efficiency and improved zonal coverage results. CON: A. Government costs probably higher than modifying 25-50 kW AM/BC tower with existing insulation and basic ground system.

Table 5-1. Alternatives Evaluation Chart (Continued)

PHASE I CONCEPT	PHASE II ALTERNATIVE	ALTERNATIVE ECONOMIC/COST IMPACTS
4. Frequency plan assigning bottom eight channels operational and top two spare.	Assign top eight channels operational and bottom two spare. Assign highest frequency channels to zones with poor ground conductivity to improve radiation frequency.	PRO: A. Antenna more efficient at high end of frequency band, increasing zonal coverage. CON: None.
5. Four to seven towers per zone outside high risk areas. Transportables consistently changing locations.	Four to seven towers with at least four outside high risk areas. Optimum location even if in risk area serves as base location except in event of attack when Phase I concept scenario applies.	PRO: A. Transportable crews live at home except for training or emergency situations (lower personnel turnover resulting). B. Base location provides training and logistics center. C. Fuel and other O&M costs minimized during non-crisis periods. D. Provides for use of existing Edgewood DIDS facility. CON: A. Optimum base station becomes target.
6. LF transportable facility has FSK digital transmission capability for LF relay.	LF transportable has no FSK digital transmission capability for LF relay.	PRO: A. Additional LF relay stations at mid-points between zone centers are not required. B. Digital relay equipment not required in transportable. C. LF transmitter confined to analog voice broadcast (A3J) mode will operate at lower average power output. CON: A. LF relay for long haul eliminated as an option.

Table 5-1. Alternatives Evaluation Chart (Continued)

PHASE I CONCEPT	PHASE II ALTERNATIVE	ALTERNATIVE ECONOMIC/COST IMPACTS
7. LF station is installed in 2-ton truck with special body.	LF station is installed in 8-wheel 6 or 10 ton special body van hauled by 6 or 10 wheel tractor; or, LF station is installed in special shelter transportable on flat bed truck or trailer.	PRO: A. Electronics equipment does not have to go to shop for truck maintenance. B. Any standard prime mover can haul trailer. C. Trailer or equipment shelter can be placed in fallout shelter without tractor prime mover. D. Special equipment shelters are standard items; truck would need special body design. CON: A. Equipment shelter requires special winches and ramps to raise/lower from transporter.
8. 85-Tower stations in 17 zones. 2 MUs per zone.	85-Tower stations in 17 zones all with hardened LF capability - no MUs.	PRO: A. Equipment is not moved, eliminating transporter costs and reducing operations and maintenance costs. B. Switch from one transmitter to another within a zone can be very fast in case of need. CON: A. Implementation cost of system much higher due to over twice the number of LF and long-haul facilities required. B. Destruction or sabotage of 85 stations eliminates LF capability. C. For maximum survivability mobile backups would still seem desirable, particularly for dual use during emergencies. D. Alternative is radical departure from basic concept analyzed and shown feasible. Some mix of fixed and mobile facilities might be more cost effective and survivable, but is beyond the scope of this analysis.

SECTION 6 - PRELIMINARY ACQUISITION PLAN

The acquisition of the LFMWS will be a complex undertaking. Not only is the system concept a new one, which will require a cautious approach in the early phases, but also there are many different participants with diversified interests. Detailed planning and scheduling will, therefore, be complicated and, to be realistic, some flexibility will have to be built into both the schedules and the system design. Accordingly, the system should be scheduled for about a 5-year implementation with annual reviews and updating of the plan based on progress and changing conditions. This system acquisition plan is divided into five major phases of about one year each, as follows:

Phase	Activities
1. System Survey	Survey, planning, scheduling
2. System Design	Design and specify system/ subsystems
3. Pilot System Implementation	Build and test prototype system
4. Interim System Implementation	Build and test interim system
5. Full System Implementation	Complete and test full system

These phases are displayed against a time scale in Figure 6-1 and are described in the following paragraphs. Some detail will be presented for Phases I and II; which will produce the data to further definitize the implementation phases.

6.1 PHASES 1 AND 2 -- SURVEY AND DETAILED SYSTEM DESIGN

This effort consists of those activities and system engineering required to produce definitive and detailed system and subsystem specifications and schedules suitable for the acquisition of contractors to engineer, furnish, install and test (EFI&T) the subsystems. Involved are the planning and conducting

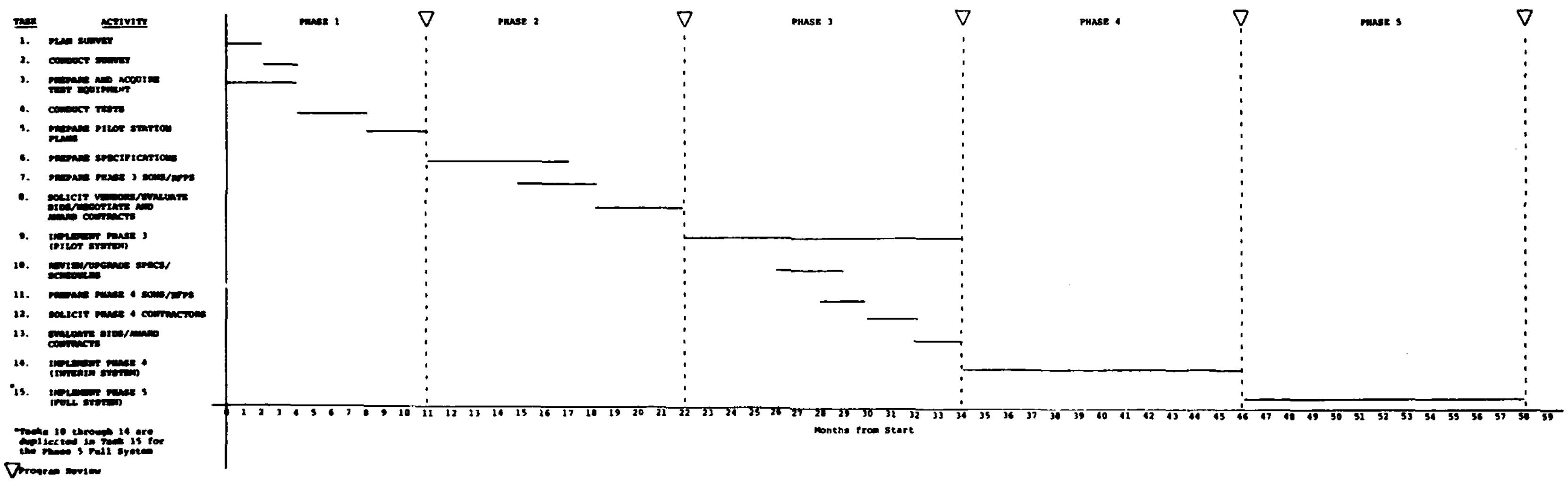

Figure 6-1. System Implementation Schedule

of thorough station surveys of all candidates in all zones; the preparation for and conduct of ground conductivity measurements and propagation tests from at least one station in each zone; the conduct of electromagnetic interference (EMI) search wherever analysis indicates a possibility of interference to or from other services; the preparation and execution of letters of understanding with each broadcast station surveyed and chosen and willing to participate; the preparation of detailed preliminary engineering plans for at least one broadcast station in each of 5 categories; the preparation of detailed and definitive system and subsystem specifications; and the acquisition of contracts for implementation of the pilot system. This process would take 22 months from availability of funds to proceed.

6.1.1 Task 1 - Survey Planning

The system engineers shall analyze the preliminary information obtained during the initial zone 2 and zone 11 candidate station visits. In addition, they shall conduct a thorough review of the other 15 zones and by means of:

a. Perusal of FCC records,

b. Telephone contact with broadcast station personnel,

c. Correspondence, and

d. Visits to stations (only if required),

they shall establish at least 4 and up to 7 stations in each zone which meet all of the requirements for incorporation into this system. Furthermore, after identification and initial contact, appointments shall be set up with each station for survey action, as described below. These appointments shall be so arranged as to provide for at least one full day on-site at each station to include the guaranteed availability of station owners, management, chief engineers, or their authorized representatives. In addition, the station will be asked to have its consultant available with one day's fees and expenses reimbursed by the Government.

This task to plan and coordinate the survey will require an estimated 120 professional man-days over a period of two months.

6.1.2 Task 2 - Site Survey

A complete site survey shall be conducted by the system engineers in cooperation with the broadcast stations and their consultants, as scheduled between those individuals during Task 1. For this purpose, all stations in all zones will be surveyed during an elapsed time of 8 weeks, by three separate two-man teams. The scheduling of Task 1 will have been so arranged as to make the movements of the surveyors as efficient as possible allowing the survey of all stations in a single zone during one continuous period. Ideally, one day will be allowed per station, one week per zone, and six weeks for six zones per team, for two of the teams. The third team will survey the more remote zones and will, therefore, do five zones instead of six in the same time frame. Zones will be assigned to teams as follows:

Team	Zones
A	1 through 6
B	7 through 11 and 14
C	12, 13, 15, 16, 17

The total field time of 8 weeks with a target of 6 weeks provides a time contingency for delays or other events beyond the control of the planners and the surveyors to accomplish the total mission.

Teams will travel to, from, and between zone centers on weekends and between station locations within zones on a daily basis either prior to the start or after regular business hours, so that the maximum productive time may be spent on-site.

During the survey period, all information required to implement an LF station at each broadcast station will be obtained in accordance with a check list and data sheet developed during Task 1. This will include:

a. All required technical data on each station

b. A precise antenna modification plan and schedule

c. Power system characteristics and requirements

d. Location and layout for fall-out shelters

e. Preliminary cost estimates

f. Plan and schedule for electrical tests if desirable

g. Agreement on plans developed reduced to a letter of understanding and signed.

Survey team chiefs shall report and coordinate by telephone on a daily basis with the program technical director to insure that maximum support is available, the survey moves as scheduled or is rescheduled, all data obtained is satisfactory, and return trips to any stations will be minimized.

Upon returning from the field part of the survey, the team personnel shall analyze and interpret data obtained, and write and publish survey reports. These reports will include conclusions and recommendations for system, zone, or station concept changes and recommendations for specific electrical tests required at selected stations. The data analysis and report part of the survey will be accomplished by 6 professionals over a period of four weeks.

6.1.3 Task 3 - Test Planning

Commencing concurrently with Task 1, equipment will be located and reserved for the purpose of making electrical measurements at selected station locations in each zone. This shall include:

1. A tunable LF receiver with panoramic display for EMI search.

2. Ground conductivity measurement equipment.

3. A tunable 1 kw output LF transmitter.

4. A tunable LF receiver (may be identical with 1 above) and field intensity measurement equipment for propagation measurements.

5. An LF signal generator for receiver calibration.

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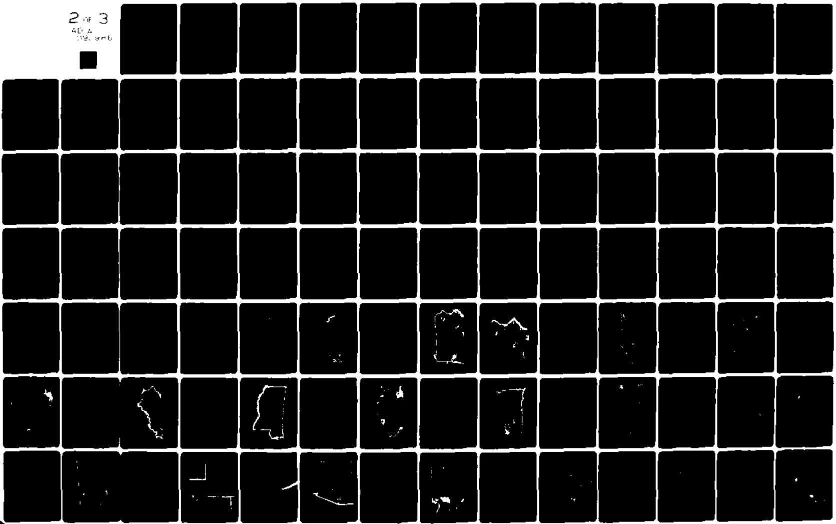

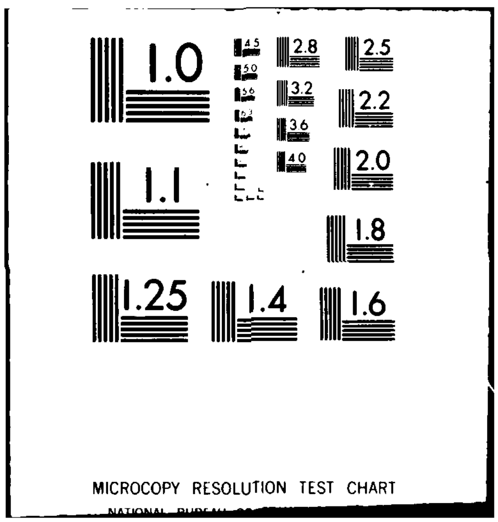
1.0
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2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART

6. A test antenna consisting of a 300-foot tower, topload and radials similar to that used for 167 kHz propagation tests in Florida in 1968, OCD report TR-64.243-68.08.

7. A full sized PARAN antenna similar to that described in Appendix C of this report. (Paragraph C.4.1.3)

The planning and preparation for the testing program is estimated at a level of two professionals for four months.

6.1.4 Task 4 - Testing

In order to provide confirmation of calculations and a firm basis for system design, four categories of tests should be considered. Details of where and when tests should take place will be determined during station surveys. The test categories are:

a. Ground conductivity tests
b. RFI (EMI) tests
c. On-site propagation tests
d. PARAN prototype design tests.

Tests a and b will be accomplished by the system engineers with the cooperation of broadcasters, as applicable. Tests in the c category will be by the system engineers with construction on-site accomplished by contractors under their supervision and control. Test d will be accomplished by the PARAN contractor with test results evaluated and approved by the system engineers.

The tests specified herein are needed to provide a solid basis for system specification and eliminate the need for possible expensive design changes after initial implementation.

This task effort is estimated at a level of three professionals for an elapsed period of four months.

6.1.5 Task 5 - Station Modification Plans

After completion of tests and analysis of data, the system engineers shall, with cooperation of the broadcast station consultants, draw up detailed plans for the required construction and modification of facilities of the broadcast stations designated for the pilot system. These plans for the pilot system will form a basis for system specification and will include at

least one of each type of station modification or construction program required for the entire system. Two professionals for three months are required.

6.1.6 <u>Task 6 - Technical Specifications</u>

The system and subsystem technical specifications shall be prepared in such detail that competitive bids can be obtained from EFI&T contractors. The specifications shall be based upon the system operational concept, propagation requirements, information developed from the field surveys, agreements/plans prepared with broadcasters, and the testing program.

The effort for this task is estimated at a level of four professionals for an elapsed period of six months.

6.1.7 <u>Task 7 - Acquisition Packages</u>

Statements of Work, Proposal Evaluation Criteria, and Evaluation Plans shall be prepared so that FEMA may solicit contractors to EFI&T the various subsystems for the pilot system. The pilot system and subsystems are broadly described under Phase 3, below. In addition, under this task, the system engineers shall assist FEMA by preparing and reviewing the acquisition packages for completeness before their release.

This task requires four professionals for three months.

6.1.8 <u>Task 8 - Proposal Evaluation/Contract Awards</u>

The system engineers shall be available during the solicitation phase of 60 days to answer questions from vendors for clarification of RFP items, and to attend and support FEMA at bidders conferences. The system engineers shall assist the review board in the evaluation of proposals for the pilot or prototype system, in accordance with the evaluation criteria and plan prepared during Task 7. The system engineers shall assist in the elaboration of system/subsystem specifications in accordance with the winning bids from vendors for attachment as contractual obligations of the contractors. It is estimated that this total task will be at a level of four professionals for four months.

6.2 PHASE 3 - PILOT SYSTEM IMPLEMENTATION

No attempt will be made to definitize the actual detailed procedures and scheduling of events within the implementation phases (3, 4, and 5) at this stage, other than to define a logical approach and a scope for the realization of the pilot, interim, and full system capabilities. This information will be developed more precisely for the pilot system during Phases 1 and 2. The pilot system activity should consist of the following:

a. Obtain four (4) mobile units with transporters. One for Zone 2, one for Edgewood for test and training (affiliated with Zone 2), and two for Zone 11.

b. Perform modification of the DIDS facility, Edgewood for SSB, Channel 7, and alternate use of the antenna by an LFMWS MU. Obtain power connectivity for the MU.

c. Prepare three stations each in Zones 2 and 11 for pilot system operation including power, fall-out shelters, antennas, for a total of 7 stations, including Edgewood.

d. Conduct subsystem and system field acceptance and operational tests.

e. Conduct such on-the-job training as may be practical for MU crews and broadcast station personnel.

f. Obtain initial quantities of SSB spot frequency receivers.

It appears reasonable that this phase could be accomplished in one year and would be complete within 34 months after the start of the LFMWS program.

6.3 PHASE 4 - INTERIM SYSTEM IMPLEMENTATION

Shortly after the beginning of Phase 3, the Pilot System Implementation Phase, additional system engineering and preparation for Phase 4, the Interim System, should commence.

6.3.1 System Engineering

Based upon the specifications attached to the contracts of the pilot system contractors, and subsequently approved engineering changes, coupled with experience gained during the first half of the Phase 3 implementation effort, the system and subsystem specifications will be reviewed, configuration management procedures applied, and the specification and schedules will be modified to optimize system performance.

6.3.2 Preparation

The Phase 4 SOWs and RFPs will reflect all administrative and engineering changes. Contractors will be solicited for Phase 4, bids evaluated, contractors selected, contracts negotiated, and awarded before the termination of Phase 3. Contract modifications will be negotiated, if needed, for Phase 3 contractors to effect any modifications to the pilot system equipment and facilities.

6.3.3 IMPLEMENTATION

Having achieved a Pilot System capability through partial operation in Zones 2 and 11, the next step should be to achieve a partial capability in the other 15 zones, and an interim operational capability for the total system.

This will involve the following:

a. Thirty (30) MUs with transporters; two for each of fifteen zones; one delivered to each zone at contract date plus five months and the second at contract date plus 10 months.

b. Crews trained and assigned as in (a) above.

c. Establishment of zone or regional logistics centers for support of LFMWS.

d. Preparation of three stations each in Zones 1, 3 through 10, and 12 through 17 for interim system operation including power, fall-out shelters, antennas. Total of 45 stations.

e. Retrofit Zone 2 and 11 facilities, if and as required.

f. Conduct subsystem and system field acceptance and operational tests, including long-haul links from NWCs, and interfaces to EOCs.

g. Conduct such on-the-job training as may be practical and useful for MU crews and broadcast station personnel. Review and upgrade operational scenarios and procedures.

h. Provide additional quantities of SSB spot frequency receivers.

If the 45 stations selected for this phase are those presenting a minimum of problems in the regulatory, operational, and technical areas; taking into account experience gained in Phase 3, it would appear that the interim system capability could be realized one year after completion of the pilot system, or 46 months after the start of the LFMWS program.

6.4 PHASE 5 - FULL SYSTEM IMPLEMENTATION

The activities described in Paragraph 6.3 will be repeated beginning shortly after the start of Phase 4, in order to prepare for and implement Phase 5 as scheduled.

Phase 5 will involve:

a. Preparation of the additional required stations in each of 17 zones. This may be a total of between 17 and 34 or more depending on what experience indicates is the optimum number per zone to meet survivability requirements. With 34 to be activated in this phase, a total of 85 would exist plus DIDS, Edgewood.

b. Provide additional SSB spot frequency receivers.

The stations to be implemented in this phase may be those which for regulatory, operational, or technical reasons could not logically be activated earlier and therefore, by mutual consent and concurrence were scheduled for later implementation.

This phase and the planned system acquisition would end with the full system operational test approximately 58 months after start of the program.

6.5 SYSTEM MANAGEMENT PLAN

The system acquisition plan described above is probably optimistic, in view of scheduling and funding problems which could arise over a period of years. For example, no provision has been included for delays in approval for broadcast station modification authorizations and the issuance of the required permits. It is certain, however, that for this program to succeed, a considerable amount of planning and scheduling with management techniques such as PERT/CPM should be applied. A program management office should be established to control the effort of all participants, and receive and monitor progress reports.

A system engineering support group should do the system survey and design and, during implementation phases, evaluate and prescribe remedies for technical and scheduling problems. It should also conduct the subsystem and system evaluation and acceptance testing program. The Program Manager and the Technical Director would manage these functions, as well as all other aspects of system implementation.

The plan to manage and control the system acquisition should be prepared and implemented prior to the initiation of the system acquisition program. Automated PERT/CPM should be considered in this regard.

SECTION 7 - COST ESTIMATE

This section refines the cost estimates of Phase I in accordance with the preliminary system specification of Appendix C and the acquisition plan described in Section 6.

Surveys were conducted in Pennsylvania and Texas. Assuming the data collected on these surveys are representative of the remainder of the United States, they can be extrapolated to arrive at a basis for estimated costs for the total LFMWS. Table 7-1 summarizes this extrapolation and the numbers of transmit zones, stations, power plants, etc., which are the basis for this cost estimate.

To accomplish this estimate, data from many sources including vendors, consultants, contractors, and broadcasters has been utilized. For further guidance, reference has been made to the "Defense Communications Agency Cost and Planning Factors Manual," DCA Circular 600-60-1.

The following paragraphs provide the details and the estimated totals. Reference should be made to Section 6 of this report and to Appendix C for further understanding of the program being costed.

7.1 MOBILE UNIT COSTS

The estimated cost per mobile unit, whether configured as an equipment shelter or a trailer van, is $214,300. The cost for 34 units will be approximately $7,286,200. Table 7-2 gives a breakdown of the components and their individual costs. This does not include system engineering, covered below.

7.2 ANTENNA COSTS

The analysis has established three methods for providing suitable antennas for the LFMWS. Table 7-3 lists these methods, the number of each (from Table 7-1), and summarizes the estimated costs. The unit cost for each method is the average estimated

Table 7-1. LF Mobile Warning System/Subsystem Quantities

Equipment and Facilities	Number
Transmit Zones	17
Mobile Units	34
Sites*	85
- Modify Existing Antennas (10-AM, 10-FM/TV)	20 (85 x 24%)
- Joint Ventures	39 (85 x 46%)
- PARANS	26 (85 x 30%)
Demuting Receivers	50,000
Program D-Prime Impact	
- MG Sets	85
- Fallout Shelters	85

*Assumed mix of types, based on Pennsylvania/Texas Surveys.

Table 7-2. Mobile Units Components and Costs

COMPONENT	UNIT COST	TOTAL COST FOR 34
Shelter/Trailer Van	$ 20,000	$ 680,000
Transmitter	135,000	4,590,000
Dummy Load	3,100	105,400
LF Receiver	100	3,400
LF Loop Antenna	50	1,700
AM/FM/TV Receiver	100	3,400
Long-Haul Transceiver	25,000	850,000
Long-Haul Antenna	200	6,800
Data Modem	1,000	34,000
Terminal Cassette Facility	1,500	51,000
Video Display Terminal	4,500	153,000
Control Console	2,000	68,000
Test Equipment	1,500	51,000
Power Distribution	5,000	170,000
Selected Spare Parts	10,000	340,000
19" Rack	250	8,500
Installation/Wiring	5,000	170,000
Total	$214,300	$7,286,200

Table 7-3. Estimated Costs for Site Antennas

Method	Number Required	Unit Cost ($000)	Total Cost ($000)	
Modify Existing Broadcast Antennas				
- AM	10	67.5	675	1,565
- FM/TV	10	89	890	
Joint Ventures	39	89		3,471
PARAN Configurations	26	139		3,614
TOTAL				8,650

cost for doing that job, based on experience and data accumulated during the surveys. At some sites costs may be higher; at other sites costs may be lower.

The average cost to modify an AM tower is estimated at $67,500, as broken down in Table 7-4. The total for 10 - AM towers is $675,000. The average cost to modify an FM/TV tower is estimated at $89,000, as broken down in Table 7-5. The total for 10 - FM/TV towers is $890,000. The total estimated cost to modify 20 existing broadcast towers is $1,565,000, (Table 7-3).

The joint venture method involves cooperative efforts by FEMA and stations with upgrade plans to provide an optimized antenna for both. The station pays the cost of its installation as if FEMA were not involved. FEMA funds the difference between what the station needs and what is required for the LFMWS. As a basis for estimating these costs (see Table 7-6), assume that a station requires a 400 foot AM tower and a 400 foot radial system costing approximately $45,000, but the government requires a 700 foot tower and an 800 foot radial system costing $129,000. FEMA pays the incremental cost of $84,000. As another basis, assume a station plans to build an FM tower (which does not require a ground system), at a cost of $35,000. The additional ground system and insulators will increase the FEMA incremental ɔst to $94,000. With 39 joint ventures (Table 7-3), and a average unit cost of $89,000 (splitting $84,000 and $94,000), the total is $3,471,000.

The third method is the PARAN antenna configuration (refer to Table 7-7). Each installation is estimated at an average cost of $139,000. The total for 26 is therefore, $3,614,000.

The total estimated cost for antennas is therefore $8,650,000 (Table 7-3). This does not include system engineering, covered below.

7.3 OTHER SYSTEM COSTS

Other costs will be incurred in order to acquire the system. Some of these, discussed below and detailed in the referenced

Table 7-4. Modification Costs for AM Stations

COMPONENT	UNIT COST	TOTAL COST FOR 10
Coupler	$50,000	$500,000
Radial Extension	3,000	30,000
New Base Insulator	5,000	50,000
Enlarge Diameter	2,500	25,000
Top Load	5,000	50,000
Testing	2,000	20,000
TOTAL	$67,500	$675,000

Table 7-5. Modification Costs for FM/TV Stations

COMPONENT	UNIT COST	TOTAL COST FOR 10
Coupler	$15,000	$150.000
Radial System	12,000	120,000
Folded Unipole Kit	5,000	50,000
New Base Insulator	5,000	50,000
Top Load	10,000	100,000
Insulated Guying	40,000	400,000
Testing	2,000	20,000
Total	$89,000	$890,000

Table 7-6. Joint Venture Costs

Broadcast Station Requirements		LFMWS Requirements	
400 ft. AM Tower	$41,000	700 ft. Insulated Tower	$ 121,000
400 ft. Radial System	4,000	800 ft. Radial System	8,000
TOTAL	$45,000	TOTAL	$ 129,000
		INCREMENTAL DIFFERENCE	84,000
400 ft. FM Tower	$35,000	700 ft. Insulated Tower	$ 121,000
Radial System	N/A	800 ft. Radial System	8,000
TOTAL	$35,000	TOTAL	$ 129,000
		INCREMENTAL DIFFERENCE	94,000
		AVERAGE INCREMENTAL COST	89,000
		TOTAL INCREMENTAL COST FOR 39 STATIONS (39 x $89K)	$3,471,000

Table 7-7. PARAN Configuration Costs

COMPONENTS	UNIT COST	TOTAL COST FOR 26
Four Elements/Four Helices/Associated Material	$ 125,000	$3,250,000
600 Ft. Outside Radial System	7,000	182,000
Counter-Weights for Ice	1,000	26,000
Installation	6,000	156,000
TOTAL	$ 139,000	$3,614,000

Tables, are directly chargeable to the LFMWS. The estimated costs for fallout shelters and emergency generators are allocable to Program D-Prime, and these are also covered in detail in Section 7.4.

7.3.1 Site Surveys (Table 7-8)

A detailed survey will be conducted to select each of the 85 sites, and acquire system design information. Since the 85 sites are divided into 17 Transmit Zones, the surveys will be conducted zone by zone.

Planning and coordinating the overall survey effort is estimated at 120 professional man-days during a period of two months. This requires 3 engineers for that period at $5,000 per man-month. The total is $30,000.

The survey field effort based on this plan will take 8 weeks. It will require 3 two-man field engineering teams. The field engineering estimated cost is $55,500. Supervision of the teams from the project office is $4,600. Additional costs for per diem, travel, air fare, rental cars and gasoline bring the total for the field survey to $95,000.

Each broadcast station will be asked to have its consultant available for 1 day, when it is surveyed, at a total charge to FEMA of about $59,500.

The survey data analysis and report will be accomplished by the 6 survey engineers in the 4 weeks following the survey at an estimated cost of $27,750.

The estimated survey total cost is $212,250.

7.3.2 System Engineering and Project Management (Table 7-9)

Mobile unit construction and site antenna work will be done by Engineer, Furnish, Install, and Test (EFI&T) contractors. Tables 7-2 and 7-3 detail the components and total cost estimates for these parts of the project. Not included is the detail and system engineering which the EFI&T contracts must accomplish. It is reasonable to estimate that such engineering costs will approximate 10 per cent of the total costs detailed in Tables 7-2 and 7-3.

Table 7-8. Survey Costs

COST ELEMENT	BASIS	TOTAL	
• Planning	3 men for 2 months (3x2x$5,000)		$ 30,000
• 17-Transmit Zone Surveys	6 men for 8 weeks (in field)	$55,500	
	Per Diem	22,500	
	Air Travel	6,500	
	Rental Cars	5,900	
	Supervision (Head Office)	4,600	
			95,000
• Broadcast Station Consultants	1 man for one day at each of 85 stations ($300 each) plus 85 RT Airfares ($400 each)		59,500
• Data Analysis/ Report	6 men for 4-weeks (Head Office)		27,750
			$212,250

Table 7-9. System Engineering and Project Management Costs

COST ELEMENT	BASIS	TOTAL
SYSTEM ENGINEERING		
• EFI&T Contractors	10 Percent of Tables 7-2 and 7-3 total costs (.1 x $15,936,200)	$1,594,000
• Government	6 Engineers x 4 Acquisition Years x $60,000/Man Year (6 x 4 x $60,000)	1,440,000
		$3,034,000
PROJECT MANAGEMENT	10 Percent of EFI&T Acquisition Costs .1 x ($15,936,200 + 1,594,000)	$1,753,020
SYSTEM ENGINEERING AND PROJECT MANAGEMENT	All of the Above (Does Not include survey engineering costs in Table 7-8)	$4,787,020

Under system engineering, therefore, $1,594,000 is estimated to be required by the EFI&T contractors.

The government (FEMA) must, after completion of the surveys, design and specify the system; prepare statements-of-work for the contractors; solicit bids; award contracts; monitor and control the work effort; and test, evaluate, and accept the various subsystems. It is estimated that, on the average, the government will require 6 engineers during the last 4 acquisition years, over and above the first year survey and planning effort. This totals $1,440,000.

In addition, a Project Management Office must be set-up, a project data base constructed, a (possibly automated) PERT/CPM system established and the many project activities carefully controlled and coordinated. For this activity, it is reasonable to estimate 10 per cent of the EFI&T contract total (Tables 7-2, plus 7-3, plus the EFI&T engineering costs). This 10 per cent totals an estimated $1,753,020.

The total estimate for system engineering and project management is, therefore, $4,787,020.

7.3.3 Documentation

Acquisition contracts should specify provision of standard commercial equipment instruction books, drawings, schematics, and parts lists. Acquisition contracts should also specify the inclusion of customized as-built subsystem drawings, and operations and maintenance manuals, including test procedures, spare module listings and the like. All of the costs for this documentation are included in the EFI&T estimates.

Overall system O&M instructions, as-built antenna, coupler and tower modifications drawings and overall system procedures will be prepared by the government systems engineers, and are included in the government system engineering cost estimate.

7.3.4 Test and Evaluation (Table 7-10)

The system test and evaluation engineering costs are included in EFI&T contract system engineering estimate, and in the overall

Table 7-10. Test and Evaluation Costs

COST ELEMENT	BASIS	TOTAL
<u>ENGINEERING</u>	EFI&T Contractors and Government Engineering Costs to Plan and Do Testing	*
<u>OTHER TESTING COSTS</u>		
• Expenses for Field Testing	3 Engineers for 4 months including per diem, air travel and rental cars	$ 25,000
• Test Equipment Rental	Van plus 1 KW transmitter, tunable LF receiver, panoramic display, recorder, etc.	$ 35,000
• LF Test Antenna	300 Foot (91 meter) transportable tower with a top load, guys and radials	$ 25,000
• Test Antenna Erection	Contract cost to erect/tear-down LF test antenna at approximately 17 locations	$170,000
		$255,000

*Included in System Engineering (Table 7-9).

government system engineering estimate. Other costs for the test program discussed in Section 6.1.4 are estimated at $255,000, total.

7.3.5 Authorization/Frequencies/Environmental Impact

Neither the broadcasters nor FEMA have to pay license fees. However, modifying broadcast station antennas, which will alter radiation patterns, and new construction during joint ventures will require license modification applications, construction permits, and environmental impact analyses which are formulated into statements on the applications. These actions will require the broadcast stations to obtain the services of consulting engineers at the cost of about $250 per day plus about $50 per day expenses. It is estimated on the average that consulting services for two man-weeks per station will be required. With 59 stations either having antennas modified or involved in joint ventures, the approximate cost for consultants will be $300 x 10 work days for services and expenses, or $3,000 per station, plus average air travel expense of $400 per station. Thus, $3,400 per station times 59 stations is a total of $200,600, estimated cost.

7.3.6 Initial Training Costs (Table 7-11)

All initial training will be conducted at Edgewood or another central location. Each person selected for a mobile unit team will attend a two-week course. There will be five people per mobile unit. Approximately 10 logistics support center personnel should also attend. Since there will be 34 MUs and 10 logistics centers, the total personnel to be trained will approximate 180.

The course preparation and instructor costs are included in the government's system engineering cost. However, the student costs total $383,680, as shown in Table 7-11. These costs include student salaries, rental car costs (4/students/car) and gasoline for local travel, air fare, and per diem for the two-week training period.

Table 7-11. Initial Training Costs

COST ELEMENT	BASIS	TOTAL
Course Preparation	By Government Project Management and System Engineering	*
Instruction	By Government Project Management and System Engineering	*
Student Salaries	180 Students x Average 2-Week Salary of $1,055	$189,900
Student Local Transport	45 Rental Cars @ $22/day for 12 days ($11,880) plus gasoline of $20 per car ($900)	12,780
Student Air Fare	180 Students x Average Air-Fare of $400	72,000
Student Per Diem	180 Students x $50 per diem x 12 days	108,000
		$382,680

*Included in Government Project Management and System Engineering Estimates (Table 7-9).

7.3.7 Demuting Receiver Costs

Based upon a total of 50,000 LF receivers to be acquired, estimates were solicited from several prospective suppliers. The budgetary estimates received ranged from $350 - $600 per receiver. This appears excessive and requires further investigation. The target cost for a receiver using integrated solid state circuitry should be no more than $100 including internal and external antennas. Using this figure for the purpose of this estimate, the receivers will cost $100 x 50,000 or $5,000,000.

7.3.8 Edgewood Modifications

A Westinghouse representative stated that to convert the transmitter to SSB would be an extremely complex and costly task. He further indicated that it would probably cost as much as a new transmitter ($570,000). Even then, there would be no assurance that the required linearity could be achieved. Consequently, it would be more economical to replace the present Edgewood equipment with a tube PA transmitter and an additional 2000 CFM cooling system at a total cost of approximately $200,000, which is used in this estimate.

7.3.9 Logistics Centers (Table 7-12)

There will be a Logistic Center at each of the 10 FEMA Regional Centers. These are estimated at a cost of $50,000 each. Thus, the total is 10 x 50,000 = $500,000. This includes provision of shop and supply facilities in the hardened FRC site and initial tools, test equipment and spares.

7.4 PROGRAM D-PRIME COSTS

Section 3.10 of this report provided an analysis which resulted in additional costs for Program D-Prime to upgrade 85 stations because of the requirements for larger generators and fallout shelters. Reference is made to Table 7-13.

TABLE 7-12. Logistic Center Costs

COMPONENT	COST	COST FOR 10
Construction • Work Bench • Electrical Outlets • Space Modifications	$ 5,000	$ 50,000
Tools and Test Equipment • Set of Basic Tools • Oscilloscope • Signal Generator • Frequency Counter • Volt-ohm Meter • Power Meter • Printed Circuit Board Testers	20,000	200,000
Spare Parts • Tubes • Spare Modules • Printer Circuit Boards • Transistors • Electrical Components • Resistors, Capacitors • Spare Wiring	25,000	250,000
Total	$50,000	$500,000

Table 7-13. LFMWS Capital Costs Allocable to Program D-Prime

ELEMENT	VALUE COMPUTATIONS	TOTAL
EMERGENCY POWER		
• 100KW Generators	78 x $18,000	$1,404,000
• 200KW Generators	7 x $28,000	$196,000
		$1,600,000
• Panels/ Switch Gear		
-100 KW	78 x $3,500	$273,000
-200 KW	7 x $4,500	$31,500
		$304,500
• Fuel		
-100 KW	2,880 gals x 78 x 1.25	$280,800
-200 KW	6,480 gals x 7 x 1.25	$56,700
		$337,500
• Storage Tanks		
-100 KW	78 x 2,500	$195,000
-200 KW	7 x 7,500	$52,500
		$247,500
FALL-OUT SHELTERS	85 x 25,000	$2,125,000
	TOTAL	$ 4,614,500

Seven 10 KW to 50 KW broadcast stations will require 200 KW generators to handle their higher power and the LFMWS MU. A 100 KW generator will be adequate for a MU and each of the other 78 1 KW to 5 KW broadcast stations. Including installation, a 100 KW unit costs $18,000, and a 200 KW unit is $28,000. The generator cost will be 78 x $18,000, plus 7 x $28,000, or $1,600,000.

Associated equipment, consisting of transfer panels and switch gear, is estimated at $3,500 for each 100 KW generator, and $4,500 for each 200 KW generator. This cost will be approximately 78 x $3,500, plus 7 x $4,500, or $304,500.

Each site should also have sufficient initial fuel to run the generators at full load for 15 days or 360 hours. The 100 KW unit uses 8 gals/hr x 360 hours. This requires 2880 gallons x 78 units. The 200 KW unit uses 18 gals/hr x 360. This requires 6480 gallons x 7 units. The total initial fuel cost is estimated at $337,500.

To store this fuel will require installation of a below ground steel tank at each site. The tanks are estimated to cost $2,500 each for the 78 - 100 KW stations, and $7,500 each for the 7 - 200 KW stations. The cost for tanks is estimated to be approximately $247,500.

A shelter contractor has provided an estimate of $25,000 for each PF 500 fallout shelter, including plumbing and ventilation. This total is approximately 85 x $25,000, or $2,125,000.

The total LFMWS cost allocable to Program D-Prime is $4,614,500

The Program D-Prime data available for this analysis indicated an average fallout shelter cost of $5,000 and an average generator cost of $6,000 for stations thus far so equipped under the Broadcast Station Protection Program portion of Program D-Prime. It may therefore logically be established that the impact of the LFMWS project on Program D-Prime is the additional amount required for the provision of larger fallout shelters

and generators for the LFMWS. Since the LFMWS needs an estimated \$4,614,500 (Table 7-13) for 85 stations and Program D-Prime can apparently provide 85 stations with lesser facilities of the same type for \$11,000 x 85 = \$935,000; the Program D-Prime capital costs impact would be plus \$3,679,500.

7.5 ESTIMATED TOTAL SYSTEM COST

It is estimated that the capital cost of the Low Frequency Mobile Warning System including demuting receivers and costs allocable to Program D-Prime, in current value dollars, is \$32,088,250. Table 7-14 summarizes these costs.

7.6 SENSITIVITY ANALYSES

The site antenna costs were established by extrapolating numbers of types of modifications derived from the Pennsylvania and Texas Surveys to the full system, assuming these zones were typical of the rest of the country. If it is now assumed that these two zones are not typical of the rest of the country, but that instead, the mix of types of antenna jobs will be random, it will be possible to examine the cost variation to determine overall system cost sensitivity to our antenna assumptions.

In addition, if detailed engineering shows that it is impractical to build fallout shelters that the mobiles can enter and operate from inside, the sensitivity of total system cost to a design change to cope with this situation, would be of interest.

If, as discussed in para 7.3.7, demuting receivers cannot be procured for \$100 or less apiece, but average \$300 each, the total system acquisition cost would increase.

Regarding mobility and survivability, the mobile units themselves are expected to be more survivable than fixed facilities. In this concept, the mobile unit is sheltered and even if its tower is damaged, the mobile unit may, in due course, move to another tower so that the system and the warning

Table 7-14. Estimated LFMWS System Capital Cost

ELEMENT	COST
34 Mobile Units	$7,286,200
20 Antenna Modifications	1,565,000
39 Joint Ventures	3,471,000
26 PARAN Configurations	3,614,000
85 Site Surveys	212,250
System Engineering	3,034,000
Project Management	1,753,020
Authorizations/Freq/Environ. Impact	200,600
Testing	255,000
Training	382,680
Demuting Receivers	5,000,000
Edgewood Modifications	200,000
Logistics Centers	500,000
Costs Allocable to Program D-Prime	4,614,500
TOTAL	$ 32,088,250

capability survives. This mobility, while more economical in capital cost than hardening 4 to 7 EBS stations in 17 transmit zones and providing each with an LF capability, would be more expensive to operate and maintain.

Table 7-15 is a cost impact comparison between the number of types of antennas based on the surveys and a random selection. It also shows the impact of the costs of fallout shelters with and without MU vaults, and MU costs with and without moveable control consoles, which would be placed in the shelter if the MU remained outside.

It is apparent that the total system cost rises 1.4% in response to change in the assumption on antennas, but reduces 3.9% in response to a reduction in shelter size and complexity.

Table 7-15 (continued) provides a comparison and cost impact for a non-mobile alternative in which 5 hardened EBS stations in each of the 17 zones would be provided with fixed, EMP hardened LF transmission facilities. While this change would not reduce the requirements for EMP and fall-out protection, it would reduce training requirements and obviate the need for separate logistics centers. It would increase the cost of EMP protected LF and long haul equipment. The system engineering and project management costs would likewise increase. From the table it may be seen that the approximate total system cost impact is an increase of about 37.9%.

For the alternative involving higher than estimated demutable LF receiver costs, say $300 each in quantities of 50,000, the impact on the mobile system total cost from Table 15 (continued) is about 31.2%. It therefore appears imperative that a low cost no-frills receiver, as specified in Appendix C, para. C. 6, must be developed for this application, in order to keep its cost down, and its O&M simple and reliable.

Table 7-15. Cost Comparison and Impact

Preliminary System Specification		Random Antenna Requirements		No MU Vault
Element	Cost	Element Variation	Cost Variation	Cost Variation
34 Mobile Units	$ 7,286,200	34 Mobile Units	$ -	$ 34,000
20 Antenna Modifications (10 AM/10 FM)	1,565,000	25 Antenna Modifications (12 AM/13 FM/TV)	402,000	-
39 Joint Ventures	3,471,000	25 Joint Ventures	(1,246,000)	-
26 PARAN Configurations	3,614,000	35 PARAN Configurations	1,251,000	-
85 Site Surveys	212,250	85 Site Surveys	-	-
System Engineering	3,034,000	System Engineering	-	-
Project Management	1,753,020	Project Management Support	-	-
Authorizations/Freq/Env. Impact	200,000	Authorizations/Freq/Env. Impact	30,600	-
Testing	225,000	Testing	-	-
Training	382,680	Training	-	-
Demuting Receivers	5,000,000	Demuting Receivers	-	-
Modifying Edgewood Transmitter	200,000	Modifying Edgewood Transmitter	-	-
Logistics Centers	500,000	Logistics Centers	-	-
Program D-Prime Impact	4,614,500	Program D-Prime Impact	-	(1,275,000)
TOTAL	$ 32,088,250	COST IMPACT	$ 437,600 (+ 1.4%)	($1,241,000) (-3.9%)

Table 7-15. Cost Comparison and Impact (Cont'd)

Preliminary System Specification		No. Mobile Units - 85 Hardened EBS Stations		Higher Receiver Cost @ $300
Element	Cost	Element Variation	Cost Variation	Cost Variation
34 Mobile Units	$ 7,286,200	85 LF Transmitters & Long Haul TCVRS Installed @ $214,300	$10,929,300	$ 6,800
20 Antenna Modifications	1,565,000	20 Antenna Modifications (19 AM/10 FM/TV)	-	-
39 Joint Ventures	3,471,000	39 Joint Ventures	-	-
26 PARAN Configurations	3,614,000	26 PARAN Configurations	-	-
85 Site Surveys	212,250	85 Site Surveys	-	-
System Engineering	3,034,000	System Engineering	922,550	680
Project Management	1,753,020	Project Management	1,015,185	680
Authorizations/Freq/Env. Impact	200,000	Authorizations/Frequencies/ Environmental Impact	-	-
Testing	225,000	Testing	-	-
Training	382,680	Training	(191,340)	-
Demuting Receivers	5,000,000	Demuting Receivers	-	10,000,000
Modifying Edgewood Transmitter	200,000	Modifying Edgewood Transmitter	-	-
Logistics Centers	500,000	Logistics Centers	(500,000)	-
Program D-Prime Impact	4,614,500	Program D-Prime Impact	-	-
TOTAL	$ 32,088,250	COST IMPACT	$ 12,175,695	10,008,160
			(+37.9%)	(+31.2%)

The non-mobile alternative will also have an impact on annual O&M costs. Table 7-19 following the discussion of O&M costs provides a comparison of Annual O&M costs for the non-mobile alternative vs the LFMWS. Since operation will be simplified, one full time person per LF site (like a station engineer) should suffice, versus 180 people in the mobile plan. This change provides for a large annual cost reduction. Equipment maintenance rises because of the increase in number of LF electronics facilities. AC power cost changes only slightly. Without a mobile, the cost of moving is eliminated. The cost for telephone lines and diesel fuel for testing and emergency simulation exercise remains the same. These factors result in annual O&M cost reduced by an estimated 34.5%. It may be noted by reference to capital cost increase for the non-mobile system alternative in Table 15 that this O&M cost reduction would pay back that increase in about 5 years.

7.7 PHASE COSTS

The individual cost for each of the five phases addressed in Section 6, Preliminary Acquisition Plan, has been estimated. Table 7-16 summarizes phase costs and Table 7-17 provides details.

7.8 COST SUPPORT PRESENTLY NOT AVAILABLE

The DIDS transmitter at Edgewood is not configured to operate in the single sideband mode; therefore, it would require some modifications before it could be used in the LFMWS. The manufacturer was contacted in an effort to get an estimate as to what the cost would be to convert it to SSB. The manufacturer indicated a complex and difficult task with no assurance of being able to achieve the required linearity. A modification cost equivalent to the cost of a new transmitter was quoted. This is $570,000 for a solid-state transmitter, versus $135,000 for a tube PA transmitter. Therefore, if Edgewood is to be modified it would be best to provide a new $135,000 transmitter with the additional air intake and duct system for cooling for which the total estimated cost is $200,000.

Table 7-16. Summary of Estimated Costs for Acquisition Phases

Phase	LFMWS Cost	Cost Allocable to Program D-Prime
1 - System Survey	$ 575,156	NONE
2 - System Design	382,094	NONE
3 - Pilot System Implementation	2,312,484	$ 467,182
4 - Interim System Implementation	16,088,988	2,295,624
5 - Full System Implementation	8,115,028	1,851,694
TOTAL	$27,473,750	$ 4,614,500
GRAND TOTAL: $32,088,250		

Table 7-17. Phase Break-Down Costs

PHASE	LFMWS COST	COST ALLOCABLE TO PROGRAM D-PRIME
1. System Survey		
• Planning	$ 30,000	-
• Zone Surveys	154,500	-
• Data Analysis	27,750	-
• Test Planning	40,000	-
• Test Engineering	37,906	
• Testing (other add'l costs)	255,000	
• Pilot Station Plans	30,000	
TOTAL	$575,156	
2. System Design		
• Technical Specifications	120,000	-
• Acquisition Packages	60,000	-
• Proposal Evaluation/ Contract Awards	80,000	-
• Project Management	122,094	-
TOTAL	$382,094	-
3. Pilot System Implementation		
• Four Mobiles	$857,200	-
• Edgewood Modifications	200,000	-

Table 7-17. Phase Break-Down Costs (Continued)

PHASE	LFMWS COST	COST ALLOCABLE TO PROGRAM D-PRIME
3. Pilot System Implementation (Continued)		
• Antennas		
-2 PARANS	$ 278,000	-
-2 Joint Ventures	178,000	-
-2 Modifications (1 AM - 1 FM/TV)	156,500	-
• Training	246,477	-
• Demuting Receivers (150)	15,000	-
• System Engineering/Project Management	359,763	-
• Authorizations/Frequencies/Environmental Impact Statement	21,544	-
• 6 Fall-Out Shelters and Power Plants	-	$467,182
TOTAL	$2,312,484	$467,182

Table 7-17. Phase Break-Down Costs (Continued)

PHASE	LFMWS COST	COST ALLOCABLE TO PROGRAM D-PRIME
4. Interim System Implementation		
• 30 Mobile Units	$ 6,429,000	-
• Personnel Training	136,203	-
• 45 Antenna Modifications	4,411,500	-
• Demuting Receivers (24,925)	2,492,500	-
• Authorizations/Frequencies/Environmental Statements	104,428	-
• System Engineering/Project Management	2,015.357	-
• 10 Logistic Centers	500,000	-
• 45 Fall-Out Shelters & Power Plants	-	$2,295,624
TOTAL	$ 16,088,988	$2,295,624
5. Full System Implementation		
• 34 Station Installations	$ 3,626,000	-
• Demuting Receivers (24,925)	2,492,500	-

Table 7-17. Phase Break-Down Costs (Continued)

PHASE	LFMWS COST	COST ALLOCABLE TO PROGRAM D-PRIME
5. Full System Implementation (Continued)		
o Authorization/Frequencies/Environmental Impact Statements	$ 74,628	-
o System Engineering/Project Management	1,921,900	-
o 34 Fall-Out Shelters & Power Plants	-	$1,851,694
TOTAL	$ 8,115,028	$1,851,694
TOTAL ALL PHASES	$ 27,473,750	$4,614,500

7.9 OPERATIONS AND MAINTENANCE

The primary recurring annual operations and maintenance (O&M) costs will be the salaries of operating and senior management personnel, mobile unit maintenance, power and telephone access. Refer to Table 7-18, and to 7-19 for a non-mobile alternative.

To fully man 2 MUs per zone, requires 10 personnel per zone, or a total of 170 people. Arriving at a median civil service grade level between GS-11 Electronics Technician and a GS-7 Communications Relay Equipment Operator, a GS-9 grade was considered appropriate for manning the MUs. The economic analysis factor of $25,287 per year for each GS-9 will be used to determine the annual manpower cost. This was compared with the equivalent contractor labor cost for a Senior Electronic Technician which is $36,200 per year. Therefore, it is more economical to use civil service personnel than contractors to man the mobile units. The total estimated annual manpower cost using ten GS-9s fulltime per zone, plus 10 at the logistics centers is (170 x $25,287) + (10 x $25,287)= $4,551,660.

Annual equipment maintenance, including MUs, antennas and the demuting receivers is derived by using a factor of .03 x acquisition costs, or .03 x $20,936,200 = $628,086.

It is estimated that on the average each standby mobile unit will use 2.5 KW of power on a continuous basis. Each active mobile unit will use an average of 70 KW. If each of 34 MUs moves a maximum of 26 times a year (every 2 weeks) and a move takes one day, then there will be 884 Non-operating days per year out of 34 x 365 = 12,410 operating days. If half, or 17 MUs, are active and the other half, or 17, are standby, there will be 12,410 - 844 = 11,526 operating days allocated equally at 5763 each to active and standby MUs. At a cost of about $.06 per KW-hour, using the average commercial business rate, the power cost for the standby units will be 5,763 days x 24 hours x 2.5 KW x $0.06, or $20,747. The power cost for the active units will be 5,763 days x 24 hours x 70 KW x $0.06, or $580,910.

Table 7-18. Annual Operations and Maintenance Costs

ITEM	YEARLY COSTS
Personnel (O&M)	
10 people per zone, $25,287/yr, 17 zones + 10 at Logistics Centers	$4,551,660
Equipment Maintenance	
.03 x $20,936,200	628,086
AC Power	
5763 operating days, 12 months, 17 mobiles (standby)	20,747
5763 operating days, 12 months, 17 mobiles (active)	580,910
MU Prime Mover Rental with Operator	371,280
Telephones	
5 accesses/area, $40/month, 12 months, 17 areas	40,800
Extra Cost $15/month/line, 1 lines, 12 months, 34 mobiles	12,240
Fuel Cost	
Bi-weekly testing, annual exercises	339,375
Senior Management Personnel	
1 at FEMA HQ, $50,530/yr 1 at each of 10 FEMA Regions, @ $42,907/yr	479,600
TOTAL	$7,024,698

Table 7-19. Annual O&M Cost Comparison and Impact

Preliminary System Specification		No Mobiles-85 Hardened EBS Stations	
Element	Cost	Element Variation	Cost Variation
O&M Personnel	$4,551,660	85 People vs 180	(2,402,265)
Equip. Maintenance	628,086	85 LF Stations vs 34 Mobiles	327,879
AC Power	601,657	1 LF TX per Zone Full Time	23,807
MU Prime Mover	371,280	Eliminate	(371,280)
Telephones	53,040	None	-
Fuel Cost	339,375	None	-
Sr. Mgt Personnel	479,600	None	-
TOTAL	$7,024,698	TOTAL	($2,421,859) (-34.5%)

Each mobile transmitter unit will have two telephone access lines and the monthly charge per line is $20. The basic cost can be calculated by $20 x 2 lines x 12 months x 5 antenna sites per zone x 17 zones = $40,800. Estimating that another cost of $15 per month per line will be utilized for extra charge calls for coordination and test purposes, the total price will be $15 x 2 lines x 12 months x 34 units = $12,240.

Prime movers will be utilized to move the MUs. The average cost is $35 per hour (including the driver). Each unit will be moved every two weeks. Thus, this cost is 26 moves per year x 34 MUs x $35 x 12 hours per move, or $371,280.

Annual fuel cost for operating the emergency power system is another operations and maintenance cost consideration. Each generator should be tested and operated at full load every two weeks for one hour. The seventy-eight 100 KW units each use 8 gallons per hour, so that 78 units x 8 gals/hr x $1.25 per gallon x 26 hours per year = $20,280. The seven 200 KW units each use 18 gals/hr x $1.25 x 26 hours per year = $4,095. It would be desirable to conduct a two week simulated emergency exercise of the system once a year. Assuming that the best test would involve all 85 LFMWS stations using emergency power, rather than just those containing MUs at the moment, the fuel cost for the 100 KW units would be 78 units x 8 gals/hr x 336 hours x $1.25 gal, or $262,080. The fuel cost for the 200 KW units would be 7 units x 18 gals/hr x 336 hours x $1.25 gal, or $52,920. The total annual cost for fuel then totals $339,375.

Finally, while the cost of project management is covered in the capital cost estimates for acquisition of the system, senior level personnel will be required to manage the operations and maintenance after full implementation. It is assumed that system implementation government project management personnel will, at that time, transfer to the annual O&M budget and will be augmented as required. One such manager at FEMA Hq and one at each of the 10 FEMA regions will be needed full

time. For FEMA Hq, a GS-14 is projected as the LF System Operations director with an economic analysis factor of $50,530 per year. At each of the 10 regions, a GS-13 is projected as LF System Regional Operations Manager with an economic analysis factor of $42,907 per year.

The total yearly operations and maintenance cost in current value dollars is estimated to be $7,024,698 when the system is in full operation. This represents a maximum figure, for planning purposes, which could be reduced by partial instead of full manning of stand-by MUs, a reduction in testing and exercise schedules and an increase in the time period between MU moves.

SECTION 8 - CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

Phase II of the LFMWS study has confirmed the feasibilty of the concept, provided certain technical and operational alternatives can be applied. While the program to acquire the system will be a complex undertaking, it is a practical and viable concept which could increase warning system survivability. The following conclusions are affirmed:

1. The contiguous 48 States could be adequately covered by a mobile LF system that employs 17 transmit zones, 34 (2 per zone) mobile units, approximately 85 (5 average per zone) antenna/broadcast station sites, and a number of regional logistic centers. Each station would have a fall out shelter large enough to house the mobile unit.
2. Low frequency ground wave propagation using single sideband suppressed carrier voice transmission is the preferred transmission mode.
3. Station surveys in two representative zones and research of industry and Government data indicate that AM, FM, and TV towers of appropriate height for LF transmission and located outside of high risk areas are limited in number.
4. Station surveys and analysis have uncovered two viable alternatives to ameliorate conclusion 3; the first requires the use of the PARAN type antenna, and the second, based on the relatively large percentage of AM, FM, or TV stations which have planned upgrade or expansion moves, entails joint ventures to build new antenna facilities to serve both commercial and Government needs.

5. Station surveys in two representative zones clearly indicated the wholehearted and enthusiastic cooperation of broadcast station owners, managers, and technical personnel, provided the LF operation did not adversely affect commercial operations.

6. Critical factors in the total system design are ground conductivity and radial system requirements, antenna height, and antenna voltage. Because of unusual situations regarding location of some broadcast stations, use of arrays by broadcasters, and the newness of the PARAN concept, a program of performance tests is indicated.

7. If an AM broadcast station has a tower that is a half-wave length high (at the broadcast frequency), modifications increasing its electrical height for LF are limited to those which will increase the electrical height for MF (the AM station) to no more than .625λ. This is to avoid excessive sky-wave radiation by the broadcast station.

8. A classic folded unipole design applied to a grounded tower could require a fairly high tower and also require a T or L type inductive coupling network, because the tower is considerably less than a quarter wave length. A folded unipole type of shunt feed could be applied to a shorter tower only if the tower were insulated from ground and multiple tuned at the feed point and to ground.

9. Transmitter PEP should be limited to 50 kW to reduce antenna voltage and current problems. This power limitation is acceptable for 17 transmit zones, if SSB is used.

10. The system acquisition will be complex due to its size and the large number of participants with diversified interests. Therefore, a program management group supported by a system engineering group should be established to implement the system. The program could be implemented on a realistic phased basis over a period of five years.

11. The estimated total cost for the system specified in Appendix C is $32,088,250 in capital cost, including $4,614,500 allocable to Program D-Prime, and $7,024,698 for annual O&M, when in full operation, based on current value dollars.

12. The above estimates are sensitive to the ability of industry to produce an LF receiver in the required quantities which will sell for $100 or less per unit. If the receiver were to cost $300 per unit, a procurement of 50,000 would increase the system estimated capital cost by about 31.2 percent.

13. An alternative eliminating mobile LF units but providing 85 hardened LF EBS stations would be almost as survivable, would cost about 37.9 percent more to acquire but 34.5 percent less per annum to operate. The annual savings would pay back the capital cost increase in about 5 years.

14. The LF system can serve the dual purpose of warning and recovery coordination in emergency and national disaster situations.

15. As the LF system is implemented and activated, a number of NAWAS drops to county and other local points may be eliminated, with attendant NAWAS cost reductions.

16. For the total system to accomplish its warning mission, a survivable long haul communications system is required to back up the NAWAS to get the alerting messages to the mobile units, when normal means fail.

8.2 RECOMMENDATIONS

1. A study should be conducted to develop and define the architecture for a survivable long haul system to interconnect the National Warning Centers with the mobile units at antenna locations.

2. Concurrently, action should proceed on establishing a program management office to implement the initial two phases of the acquisition plan proposed in this report.

APPENDIX A
LFMWS PHASE I STUDY
EXECUTIVE SUMMARY

PREFACE TO APPENDIX A

Phase I of this study was a preliminary analysis of the technical aspects of the basic concept. It showed that the basic concept was feasible from a technical viewpoint.

The Executive Summary from the Mobile Low Frequency Warning System Study, Phase I - Feasibility Analysis, draft report, dated 6 August 1979, is reproduced for record purposes on the following pages. Phase I provided a basis for the system design and the refined cost estimates of the Phase II effort.

It will be noted that the capital cost estimate resulting from Phase I is high compared to the estimated acquisition cost for the preliminary specification system developed in Phase II (see Sections 7, 8 and App. C). Phase II specified a change from a highly automated solid state LF transmitter, used in Phase I, to a less sophisticated transmitter with tube final amplifiers and a lower average radiated power. This single factor accounts for most of the difference in the two estimates.

It will also be noted that the annual O&M cost estimate for Phase II is considerably higher than that reported for Phase I. The factors contributing to this increase are; the use of a larger number of more highly skilled O&M personnel, the addition of senior management personnel, full power continuous operation in all zones, and fuel for testing and simulated emergency exercises in Phase II, which were not included in Phase I.

The following executive summary is unmodified, but it should be noted that the cost estimates for Phase II are the valid ones for planning purposes.

EXECUTIVE SUMMARY

ES.1 INTRODUCTION

Under a Defense Civil Preparedness Agency (DCPA) contract, DCPA01-79-C-0264, Computer Sciences Corporation conducted a study to determine the feasibility of using a Low Frequency Mobile Warning System (LFMWS) to provide a reliable, survivable national warning capability. The feasibility analysis is Phase I of two phases of the contract. Phase II includes a detailed analysis of system alternatives, on-site survey of radio and TV stations and an overall systems design with preliminary performance specifications. Phase II will be initiated if the Phase I study confirms the feasibility of the basic concept.

The system concept calls for the National Warning System to inject warning messages (national disaster, nuclear attack, post attack instruction, etc.) into the low frequency (LF) system which, in turn, disseminates these messages to all parts of the country. This LF message dissemination is accomplished by ground wave propagation which is only minimally disturbed by nuclear atmospheric effects as compared to many other radio propagation techniques.

ES.2 PHASE I STUDY EFFORT

The overall objective of the Phase I was to determine the technical feasibility of this concept. The major areas of inquiry examined includes:

- Definition and evaluation of the basic system design concept that will result in a reliable and nuclear war survivable system
- Determination and evaluation of design criteria and important system parameters
- Selection of optimum system parameters
- Establishment of preliminary antenna modification/antenna interface design

- Development of a preliminary design for a low frequency mobile transmitter unit
- Generation of a cost estimate for the LFMWS.

The critical factors that are evaluated include: regional ground conductivity, antenna ground radial system diameter, antenna height, antenna height to diameter ratio, RF power level, existing AM/MF antenna feed arrangements and FM/TV antenna land availability (for ground radial system installation).

The study revealed the basic AM broadcast station required modifications would include: installation of a newly designed coupler, modification to AM antenna coupler, possible ground radial system enlargement, possible antenna diameter enlargement, possible addition of antenna top loading, possible insulator replacements (base, guy), addition of a fallout shelter, addition of a new AM/LF station emergency motor generator system, and modification of the station alternating current distribution system.

The basic FM and TV broadcast station required modifications would include: installation of a simple capacitance coupler, addition of a new ground radial system, addition of a unipole (shunt feed technique) conversion kit, conversion from grounded guy cables to insulated guy cables, possible antenna diameter enlargement, possible antenna top-loading, addition of a fallout shelter, addition of a new FM-TV/LF station emergency motor generator system, and modification of the station alternating current distribution system.

Table ES-1 summarizes the preliminary system parameters. A preliminary mobile transmit unit configuration is shown in Figure ES-1.

ES.3 CONCLUSIONS

The major conclusions from this study are:

(1) The Low Frequency Mobile Warning System Concept is feasible. It can be implemented using standard communication/broadcast

Table ES-1. LFMWS Characteristics

Transmit Zones Per CONUS (48 States)	17
Transmit Zone Area Diameter	50 miles (80.5 kilometers)
Mobile Units Per Transmit Zone	2
Antenna Stations Per Transmit Zone	5
FM/TV Antenna Stations to be Converted	55
AM Antenna Stations to be Converted	30
LF Transmit Power	50
LF Signal Modulation	SSB
Voice Bandwidth	3 kHz
LF Frequency Band	160 to 190 kHz
LF Channels (3 kHz)	10
Mobile Transmitter Unit Truck Size	2 ton
Truck Van Size	14 feet long by 8 feet wide by 7.5 feet high (4.28 x 2.44 x 2.29 meters)
Long-Haul Communications (Potential)	Meteor Burst (Up to 2400 bps)

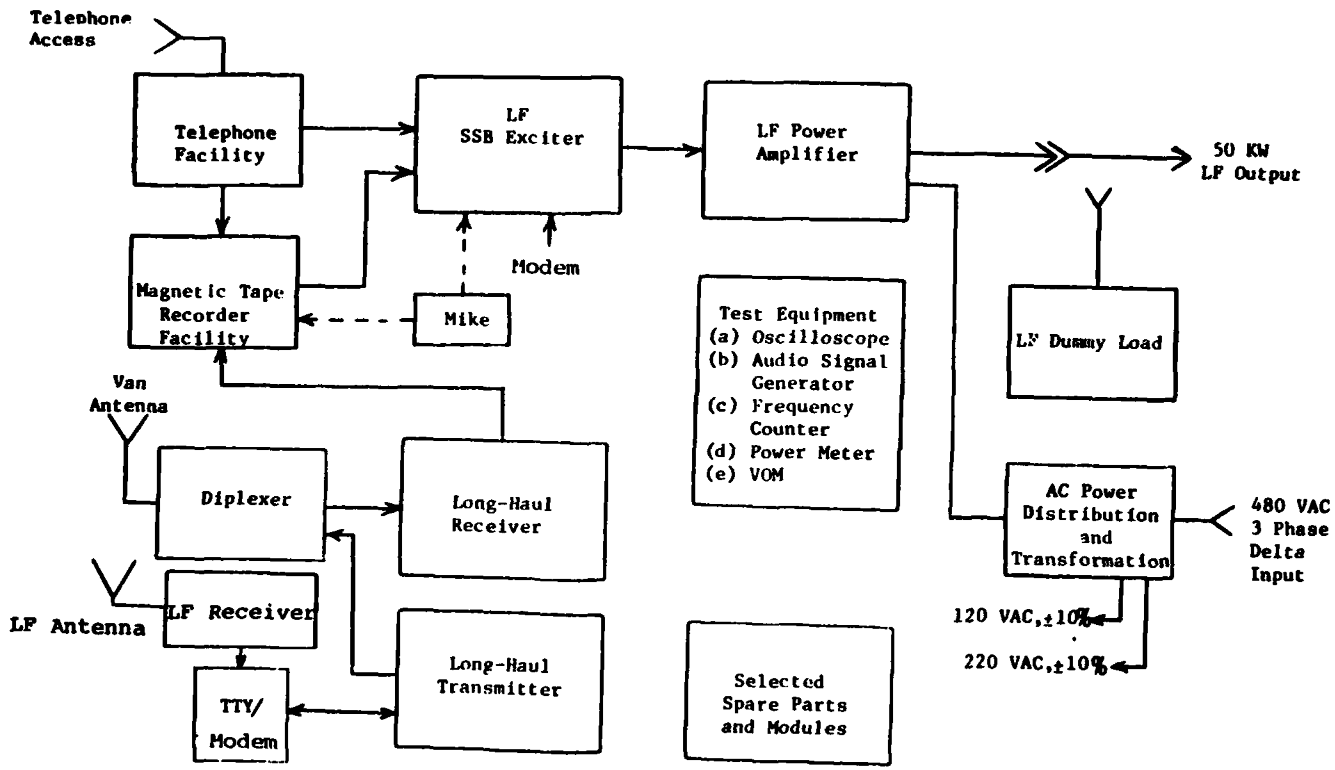


Figure ES-1. Typical LF Mobile Transmitter Unit Components and Circuit Configuration

station techniques, and a limited amount of specially designed equipment.

(2) The CONUS (48 state) system can be implemented by using 17 transmit zones, 34 mobile transmitter units (2 units per zone), 85 antenna/broadcast station sites (5 sites per zone) and 34 mobile transmitter unit storage areas. See Figures ES-2 and ES-3.

(3) Low frequency ground wave propagation by means of single side band transmission offers the best characteristics for bandwidth, channelization, and radio frequency spectrum conservation.

(4) A combination of AM, FM, and TV broadcast stations should be converted for low frequency operation to implement the system.

(5) A survey of government and industry reports indicate that there should be a sufficient number of existing AM, FM, and TV station antennas to support the projected 17 transmit zones.

(6) The preliminary estimated acquisition cost for the LFMWS, including supporting communications, is $47.6 million dollars ±10%. The annual operation and maintenance cost is estimated to be three million dollars per year.

ES.4 RELATED FACTORS

There are several related factors that should be analyzed prior to a final determination on implementing the LFMWS. These include the following:

- Identification and characteristic determination of available broadcast antenna facilities in suitable transmit zones.
- Determination of the willingness of broadcast station owners in the various transmit zones to allow the necessary modifications to be made to their station facilities.
- Determination of the system operation requirements (Interoperability between low frequency transmit zones

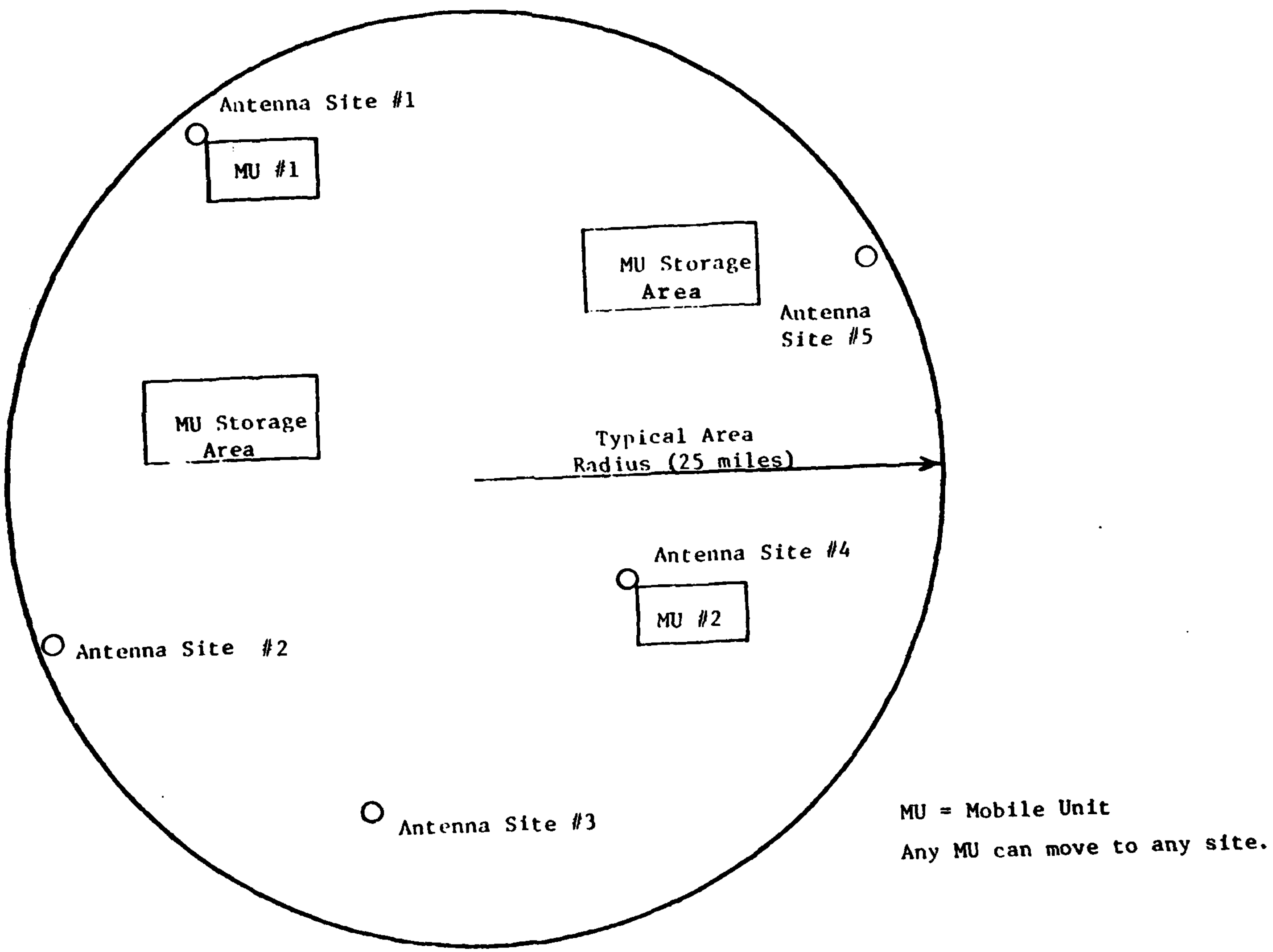


Figure ES-2. Typical Transmit Zone Utilizing Two Mobile Units and Five Antenna Sites

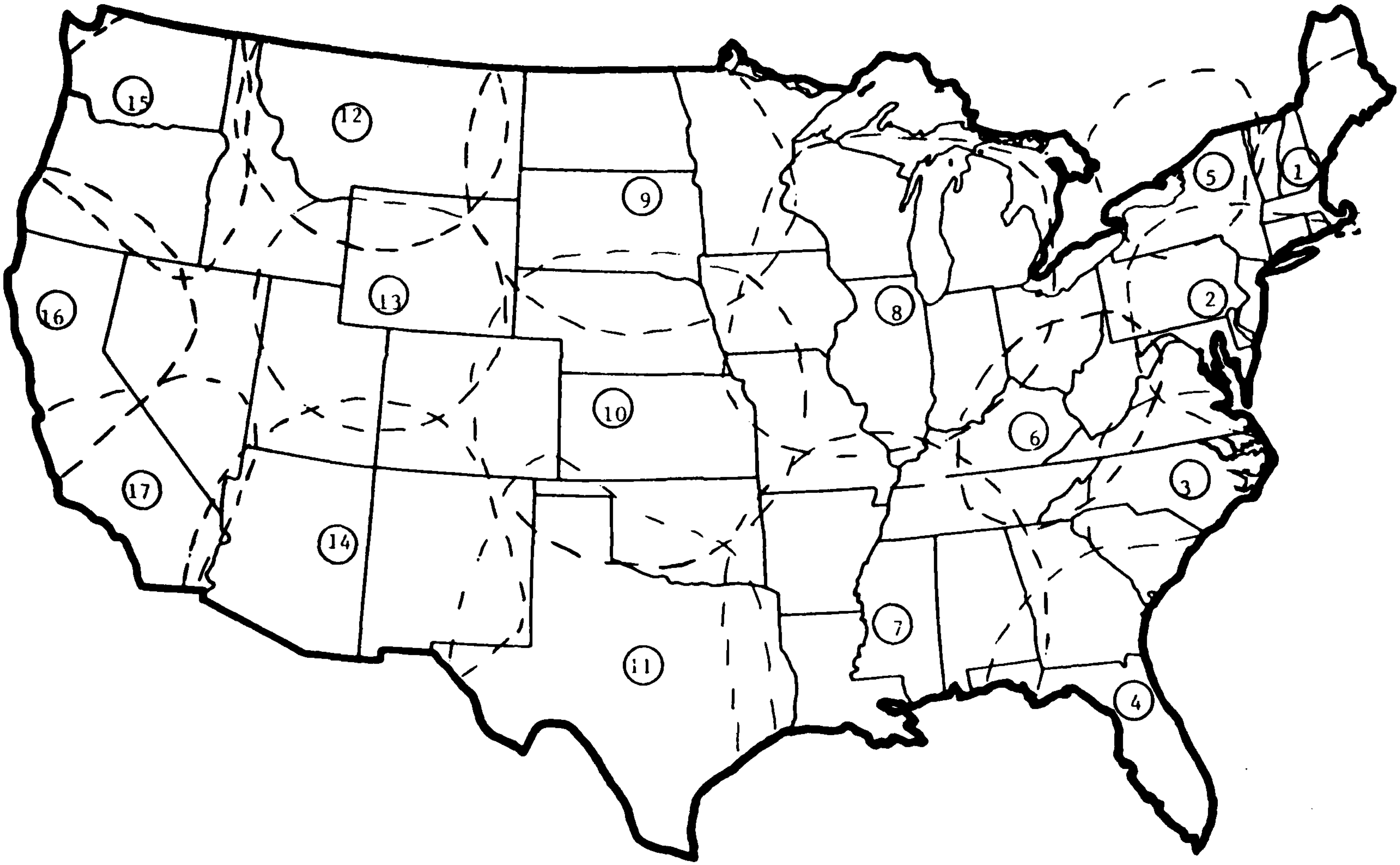


Figure ES-3. LF Groundwave Range Pattern at 500 $\mu V/m$ for Selected 50 kW Transmitter System.

and interface to the National Warning System).

- Determination of the regulatory requirements.
- Generation of a fine grain system cost analysis.
- The establishment of a firm concept for a long-haul emergency communication equipment net and the network interconnection to the National Warning System.

These items should be analyzed and resolved in follow-on studies.

APPENDIX B
TRANSMIT ZONES

APPENDIX B - TRANSMIT ZONES

B.1 GENERAL

Analysis to date has confirmed the suitability of the 17 zone concept developed in Phase I. Final determination of actual zone centers and exact numbers of zones required to cover CONUS will depend upon a full survey including ground conductivity and propagation tests from sites selected in each zone. This Appendix provides the maps for identification of candidate station locations in each zone and tables describing the preliminary candidate stations that are identified.

B.2 CONUS TRANSMIT ZONES

Figure B-1 is provided to show the location of the 17 zones with respect to each other; delineate the expected primary coverage contours; and show location of the DIDS, Edgewood Station associated with Zone 2.

A map is provided for each of the projected seventeen transmit zones, Figures B-2 through B-21. These maps were obtained from publication TR-82, September 1979, "High Risk Areas for Civil Nuclear Defense Planning Purposes", and used because they show the nuclear high risk areas. The candidate station locations are shown by means of ovals drawn around the towns and cities involved. The locations shown for Zones 2 and 11 are based on actual preliminary field surveys. The locations for all other zones result from a documentation technical analysis of broadcast station locations and characteristics. These should be confirmed by subsequent field surveys.

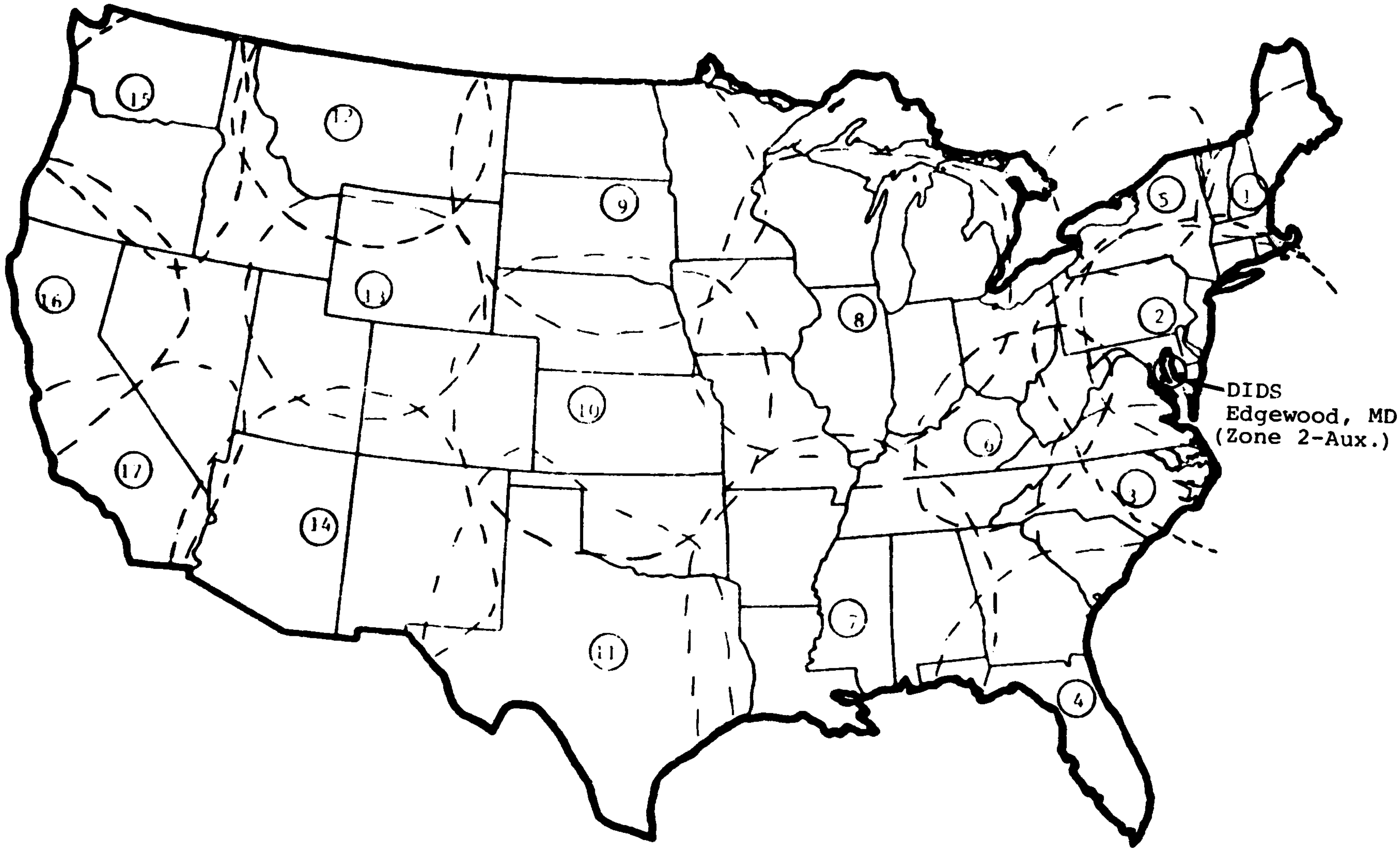


Figure B-1. CONUS Coverage Map

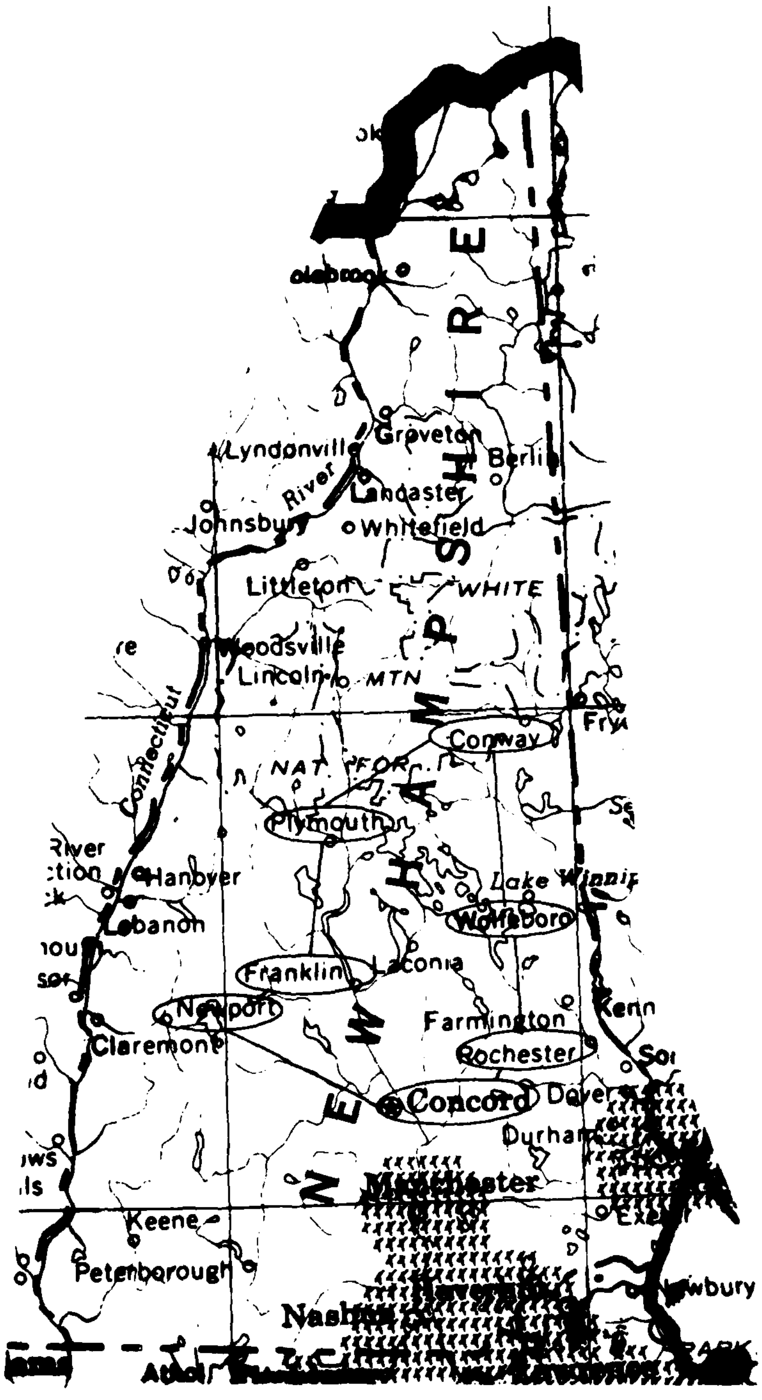


Figure B-2. Transmit Zone 1 - New Hampshire

Table B-1. STATE: NEW HAMPSHIRE ZONE: 1

CITY	CALL	MODE	FREQ.	OUTPUT POWER
CONCORD	WKXL	AM	1450 KHz	1 KW
CONWAY	WBNC	AM	1050 KHz	1 KW
FRANKLIN	WFTN	AM	1240 KHz	1 KW
NEWPORT	WCNL	FM	101.7 MHz	2 KW
PLYMOUTH	WPNH	FM	100.1 MHz	1.65 KW
ROCHESTER	WWNH	AM	930 KHz	5 KW
WOLFEBORO	WASR	AM	1420 KHz	1 KW

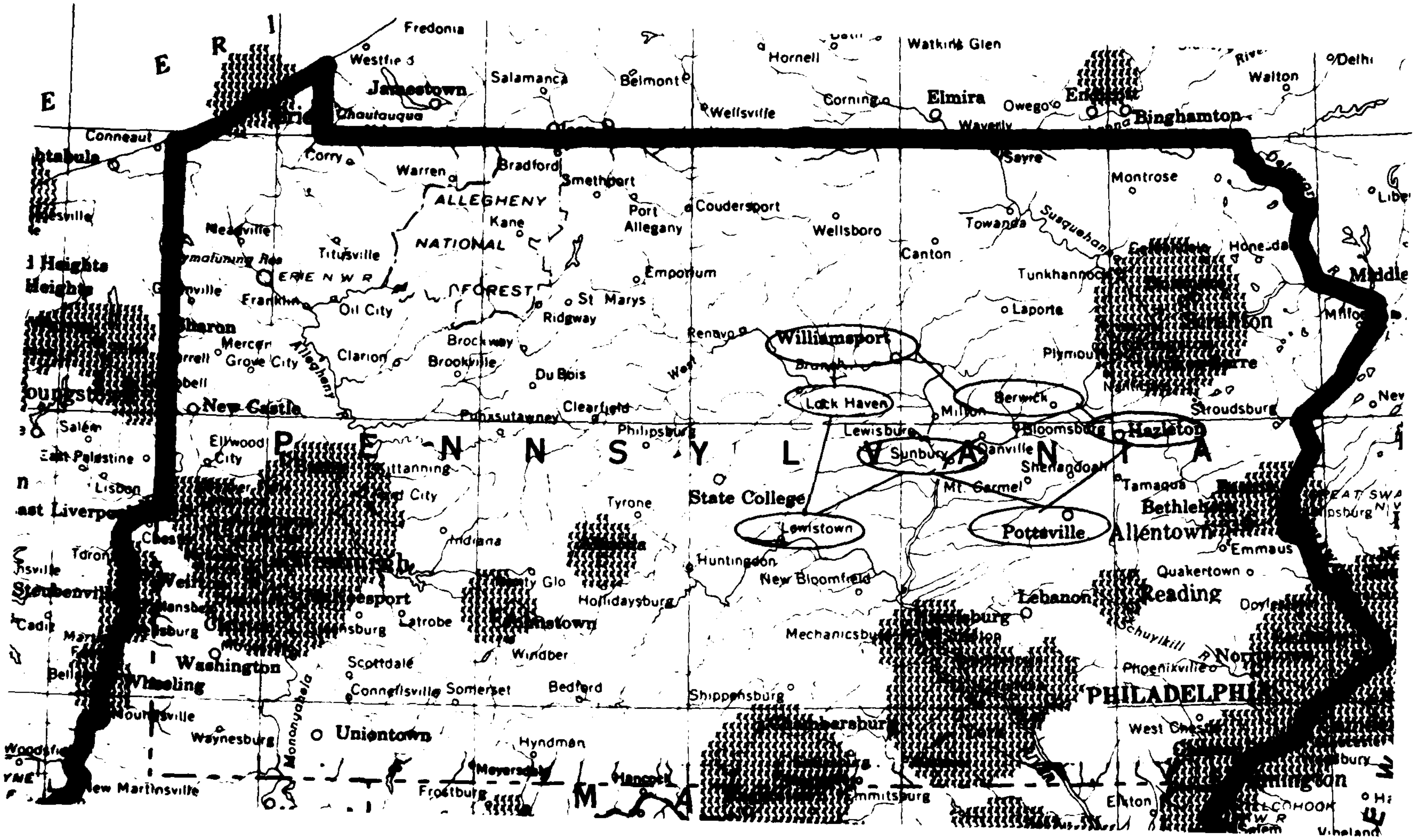


Figure B-3. Transmit Zone 2 - Pennsylvania - Excludes Edgewood

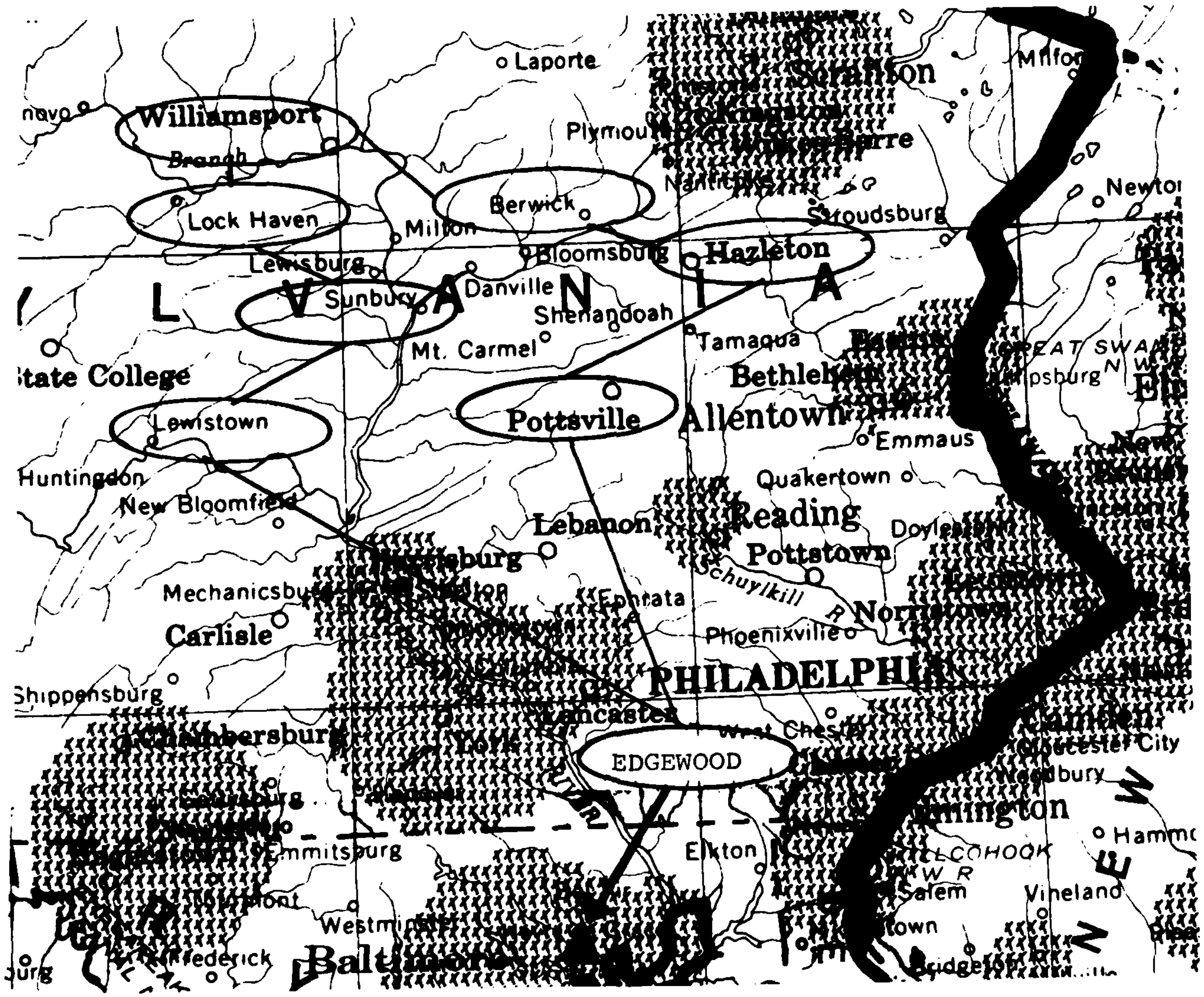


Figure B-4. Transmit Zone 2 - Pennsylvania - Includes Edgewood

Table B-2 . STATE: PENNSYLVANIA ZONE: 2

CITY	CALL	MODE	FREQ.	OUTPUT POWER
BERWICK	WBRX	AM	1280 KHz	1 KW
HAZLETON	WAZL	AM	1490 KHz	1 KW
LEWISTOWN	WKVA	AM	920 KHz	1 KW
LOCK HAVEN	WBPZ	FM	92.1 MHz	3 KW
POTTSVILLE	WPPA	AM	1360 KHz	5 KW
SUNBURY	WKOK	AM	1070 KHz	10 KW
WILLIAMSPORT	WLYC	AM	1050 KHz	1 KW
EDGEWOOD, MD	DIDS	SSB	178 KHz	25 KW

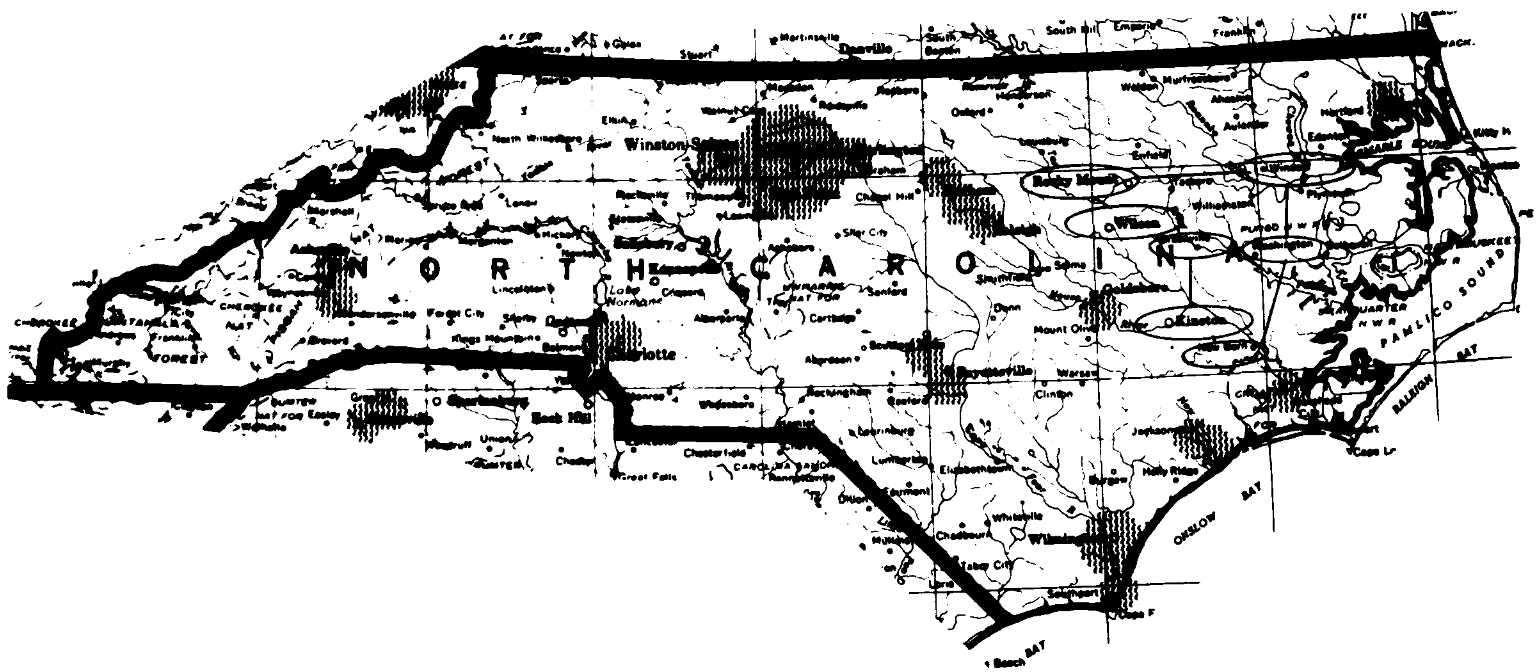


Figure B-5. Transmit Zone 3 - North Carolina

Table B-3. STATE: NORTH CAROLINA ZONE: 3

CITY	CALL	MODE	FREQ.	OUTPUT POWER
GREENVILLE	WNCT	AM	1070 kHz	10 kW
KINSTON	WFTC	AM	960 kHz	5 kW
NEW BERN	WBIC	AM	1380 kHz	5 kW
ROCKY MOUNT	WEED	AM	1390 kHz	5 kW
WASHINGTON	WITN	AM	930 kHz	5 kW
WILSON	WGTM	AM	590 kHz	5 kW
WINDSOR	WBTE	AM	990 kHz	1 kW

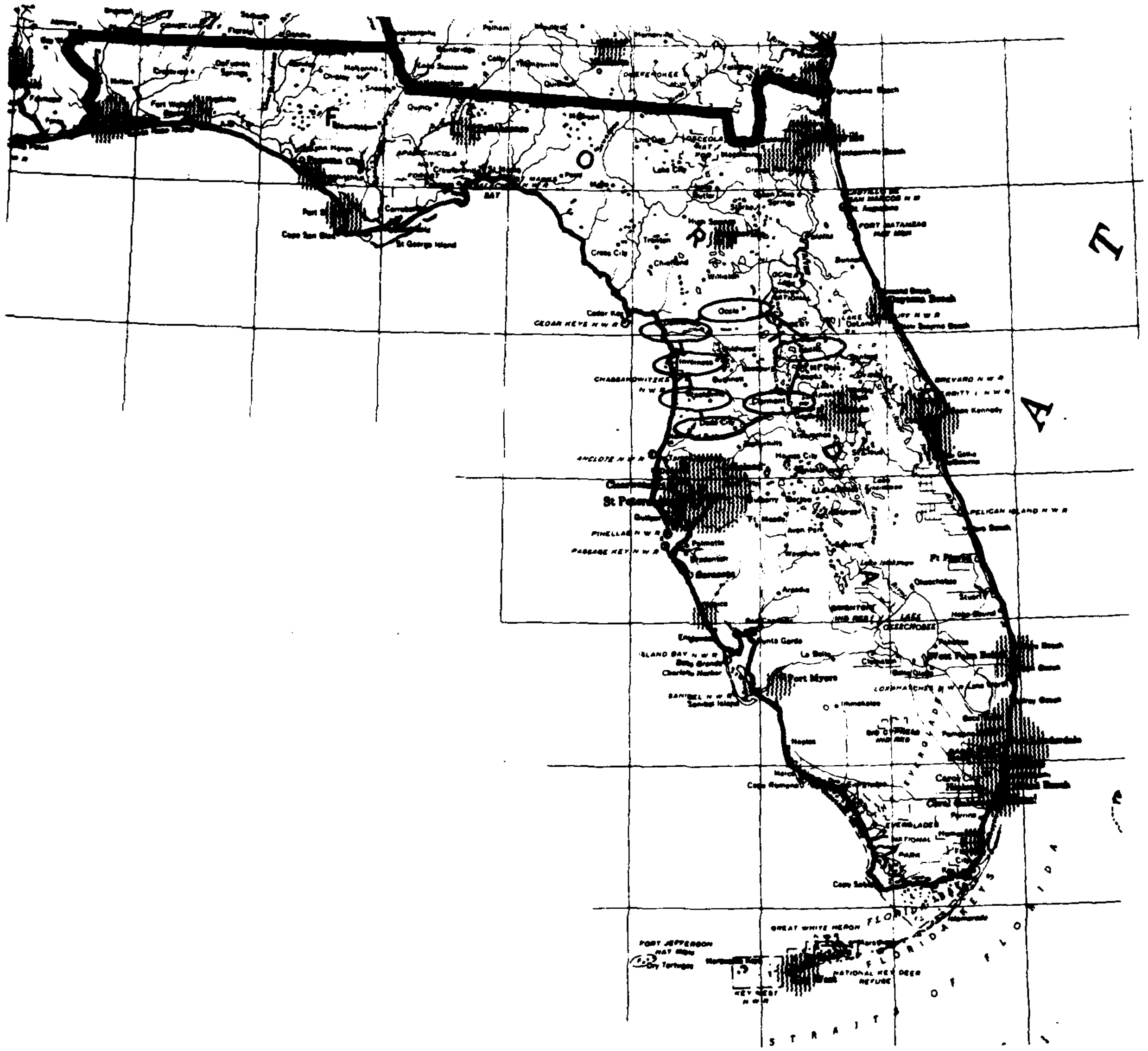


Figure B-6. Transmit Zone 4 - Florida

Table B-4. STATE: FLORIDA ZONE: 4

CITY	CALL	MODE	FREQ.	OUTPUT POWER
BROOKSVILLE	WWJB	AM	1450 kHz	1 kW
CLERMONT	WWFL	AM	1340 kHz	.25 kW
DADE CITY	WDCF	AM	1350 kHz	1 kW
DUNNELLON	WTRS	FM	102.3 mHz	3 kW
EUSTIS	WLCO	AM	1240 kHz	1 kW
INVERNESS	WYSE	AM	1560 kHz	1 kW
OCALA	WTMC	AM	1290 kHz	5 kW

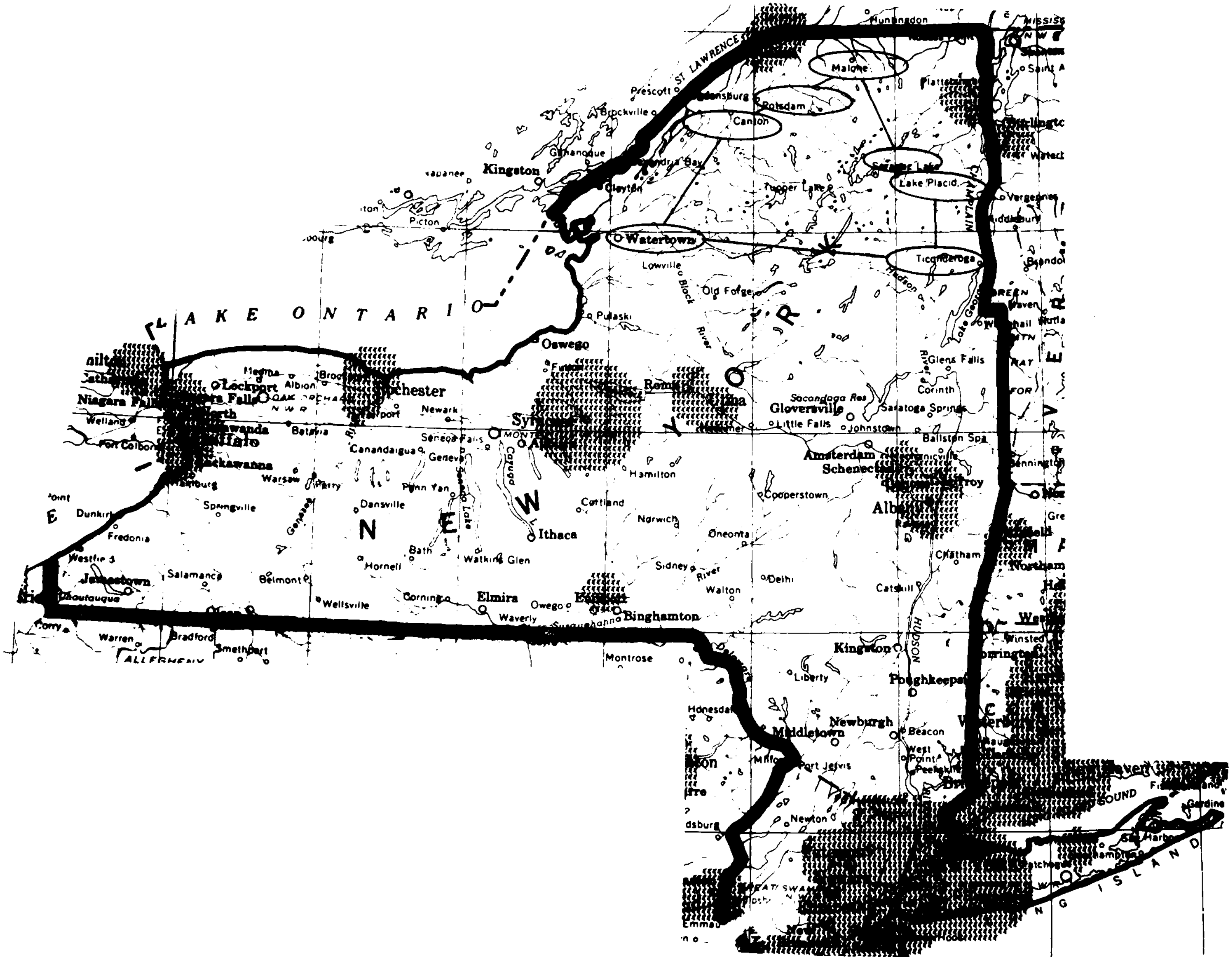


Figure B-7. Transmit Zone 5 - New York

Table B-5. STATE: NEW YORK ZONE: 5

CITY	CALL	MODE	FREQ.	OUTPUT POWER
CANTON	WSLU	FM	96.7 mHz	2.6 kW
LAKE PLACID	WIRD	AM	920 kHz	5 kW
MALONE	WICY	AM	1490 kHz	1 kW
POTSDAM	WPDM	AM	1470 kHz	1 kW
SARANAC LAKE	WNBZ	AM	1240 kHz	1 kW
TICONDEROGA	WIPS	AM	1250 kHz	1 kW
WATERTOWN	WOTT	AM	1410 kHz	5 kW

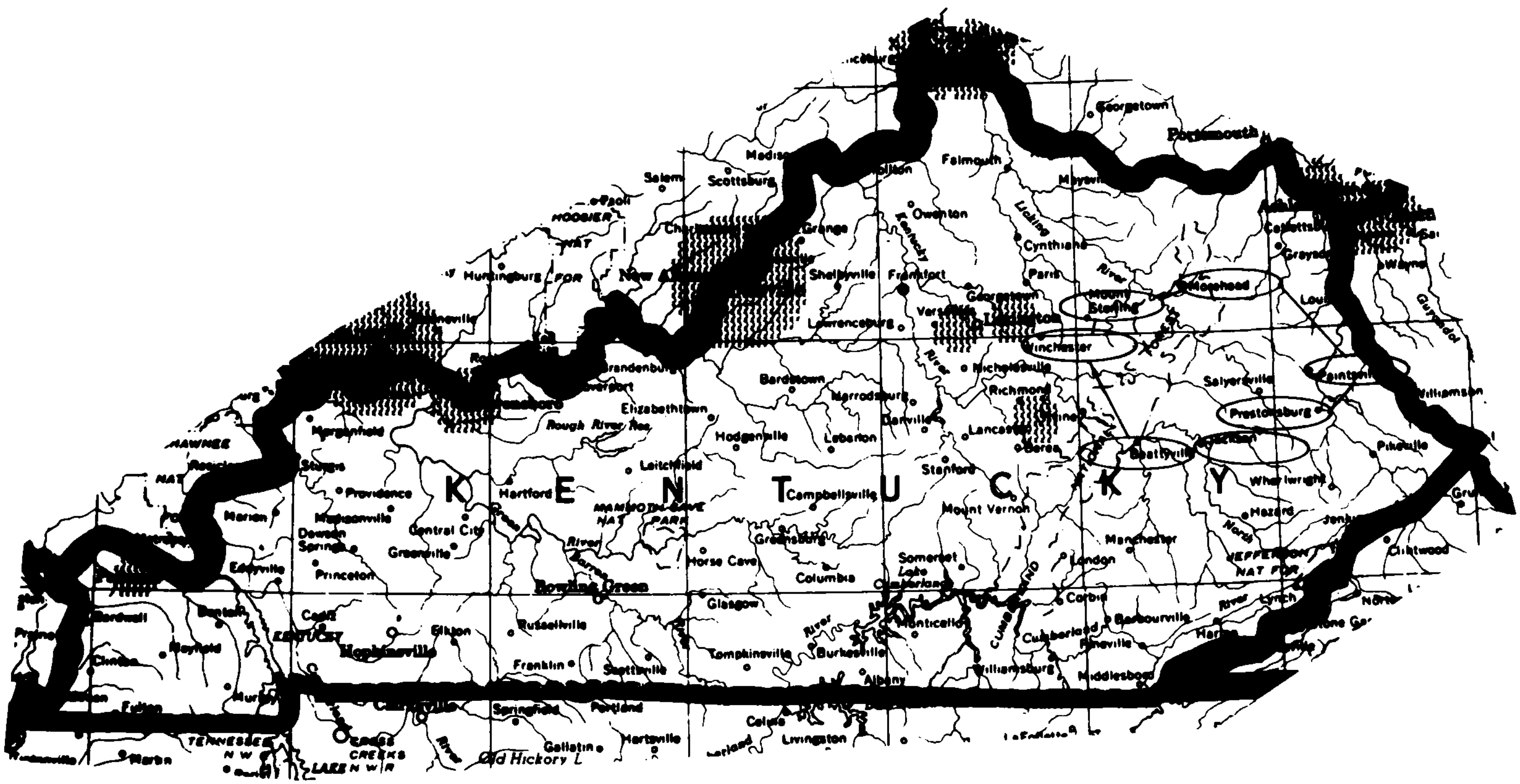


Figure B- 8. Transmit Zone 6 - Kentucky

Table B-6. STATE: KENTUCKY ZONE: 6

CITY	CALL	MODE	FREQ.	OUTPUT POWER
BEATTYVILLE	WLJC	FM	102.3 mHz	3 kW
JACKSON	WEKG	AM	810 kHz	1 kW
MOREHEAD	WMOR	AM	1330 kHz	1 kW
MT. STERLING	WMST	FM	105.5 mHz	3 kW
PAINTSVILLE	WSIP	FM	98.9 mHz	31 kW
PRESTONSBURG	WPRT	AM	960 kHz	5 kW
WINCHESTER	WWKY	AM	1380 kHz	1 kW

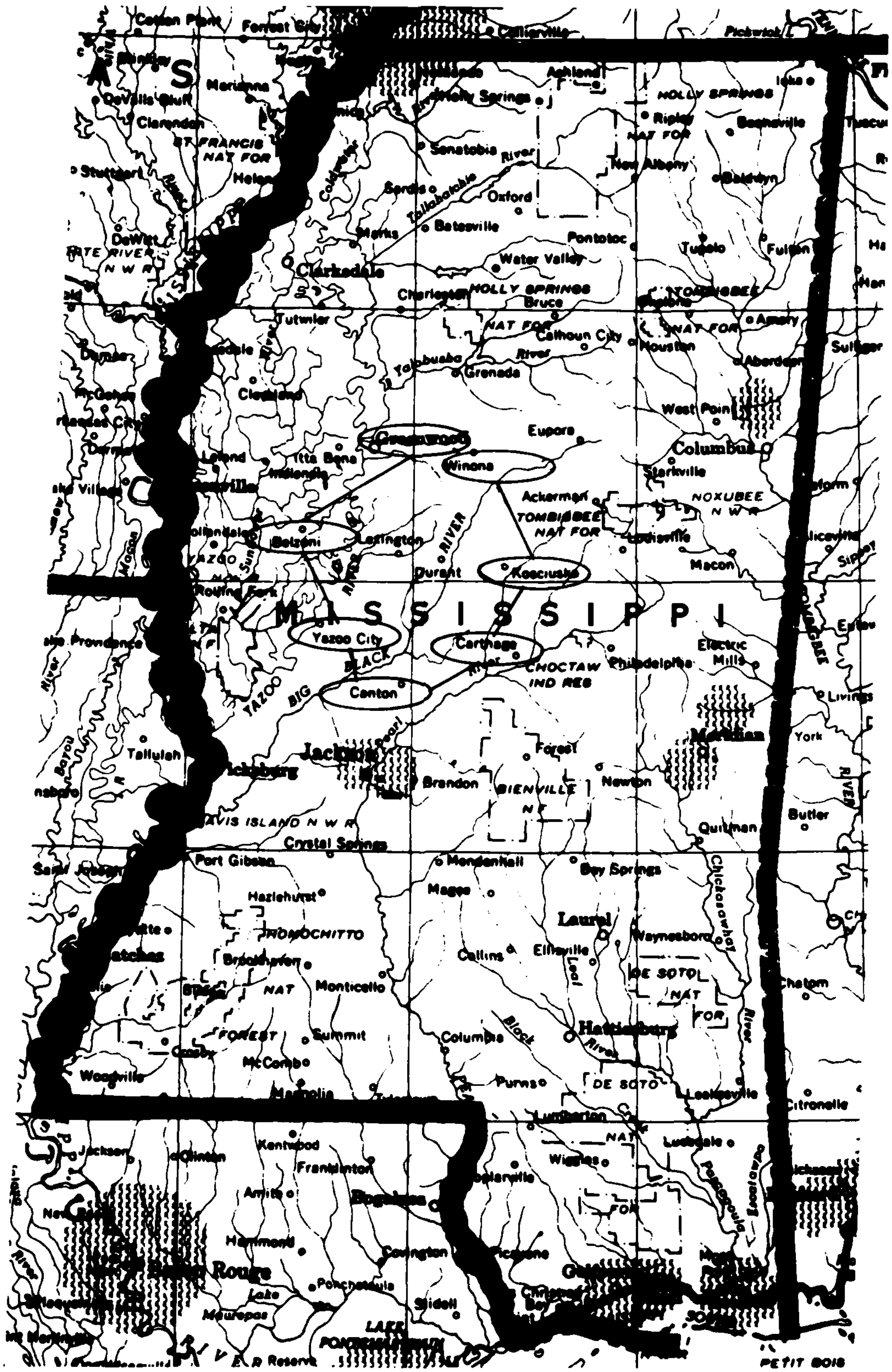


Figure B-9. Transmit Zone 7 - Mississippi

Table B-7. STATE: MISSISSIPPI ZONE: 7

CITY	CALL	MODE	FREQ.	OUTPUT POWER
BELZONI	WELZ	AM	1460 kHz	1 kW
CANTON	WMGO	AM	1370 kHz	1 kW
CARTHAGE	WECP	AM	1080 kHz	.25 kW
GREENWOOD	WABG	AM	960 kHz	1 kW
KOSCIUSKO	WKOZ	AM	1340 kHz	1 kW
WINONA	WONA	AM	1570 kHz	1 kW
YAZOO CITY	WAZF	AM	1230 kHz	1 kW

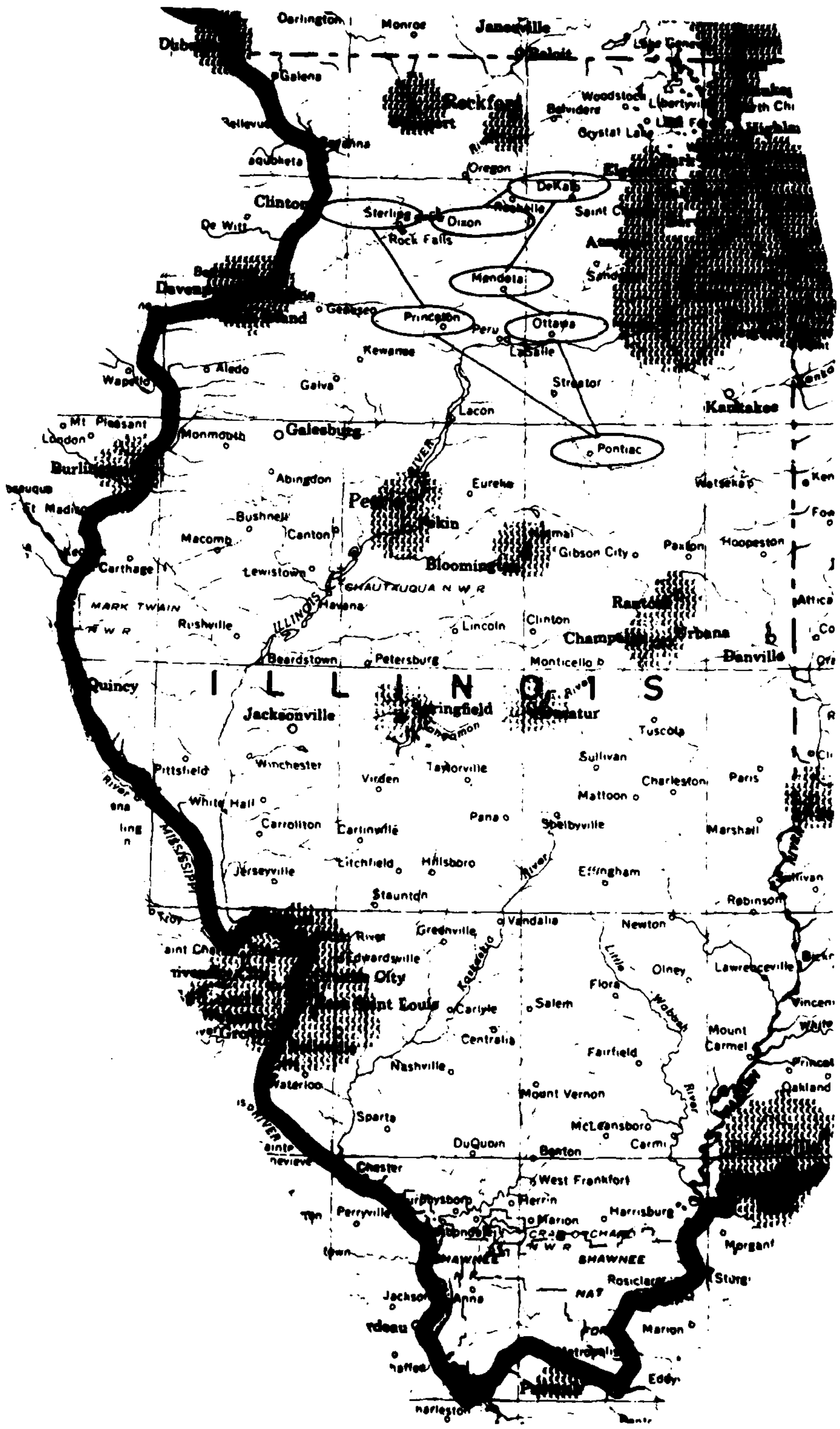


Figure B-10. Transmit Zone 3 - Illinois

Table B-8. STATE: ILLINOIS ZONE: 8

CITY	CALL	MODE	FREQ.	OUTPUT POWER
DEKALB	WLBK	AM	1360 kHz	1 kW
DIXON	WIXN	AM	1460 kHz	1 kW
MENDOTA	WLGC	AM	1090 kHz	.25 kW
OTTAWA	WCMY	AM	1430 kHz	.5 kW
PONTIAC	WPOK	AM	1080 kHz	1 kW
PRINCETON	WZOE	AM	1490 kHz	1 kW
STERLING	WJVM	FM	94.3 mHz	3 kW

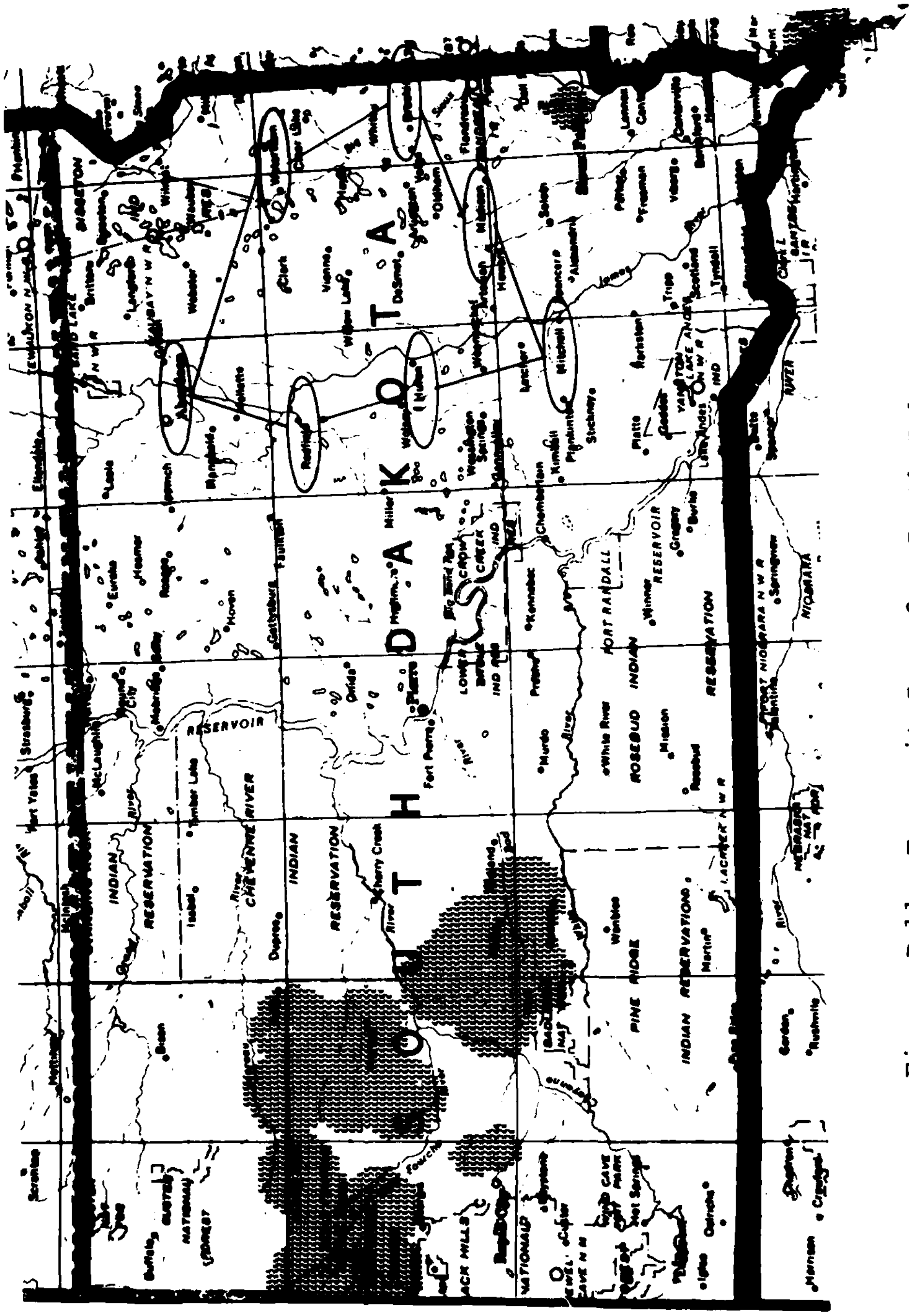


Figure B-11. Transmit Zone 9 - South Dakota

Table B-9. STATE: SOUTH DAKOTA ZONE: 9

CITY	CALL	MODE	FREQ.	OUTPUT POWER
ABERDEEN	KABY	TV	CH. 9	47.5 KW
BROOKINGS	KESD	TV	CH. 8	51.3 KW
HURON	KIJV	AM	1340 kHz	1 kW
MADISON	KJAM	AM	1390 kHz	.5 kW
MITCHELL	KORN	AM	1490 kHz	1 kW
REDFIELD	KFCB	AM	1380 kHz	.5 kW
WATERTOWN	KWAT	AM	950 kHz	1 kW

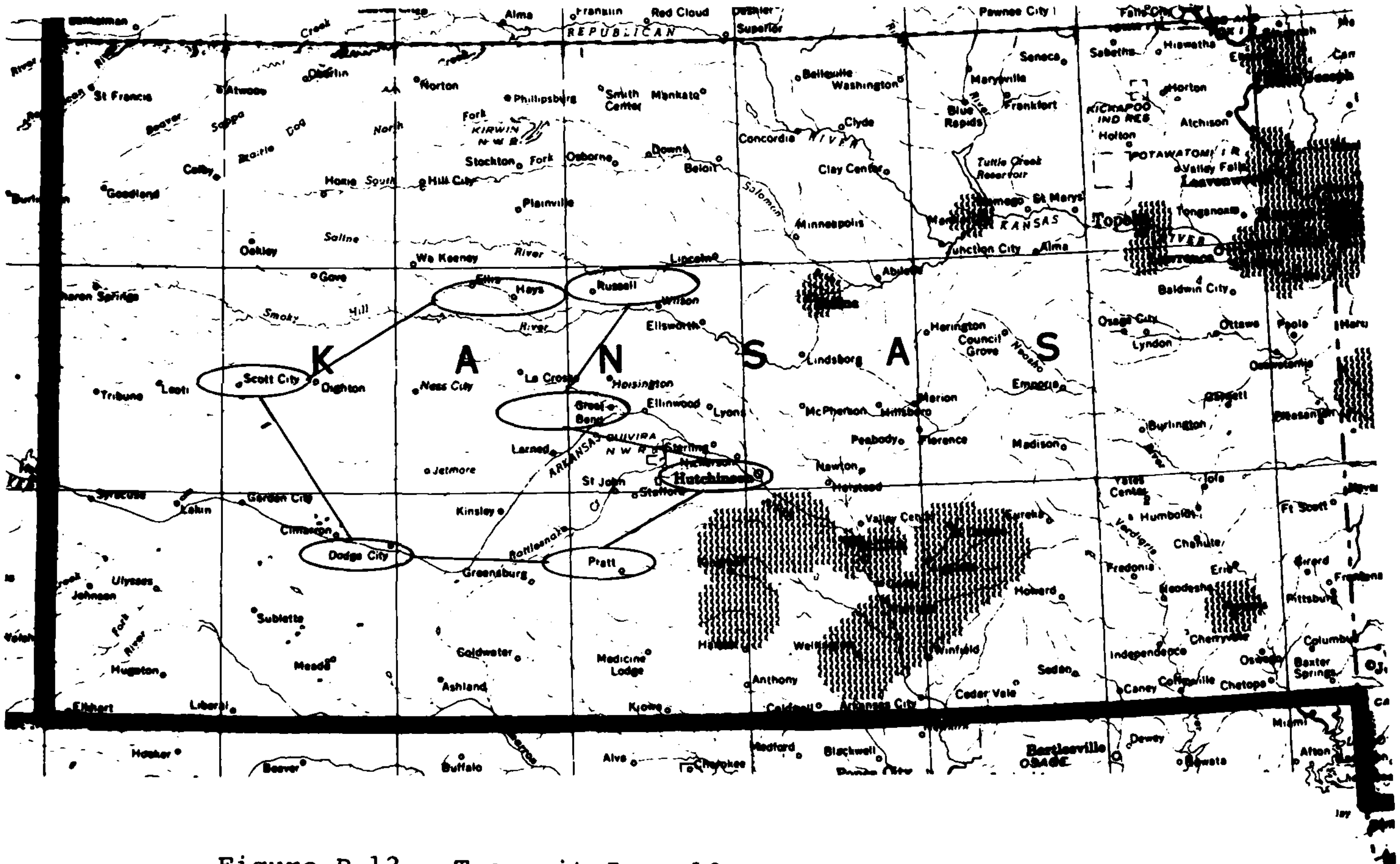


Figure B-12. Transmit Zone 10 - Kansas

Table B-10. STATE: KANSAS ZONE: 10

CITY	CALL	MODE	FREQ.	OUTPUT POWER
DODGE CITY	KGNO	AM	1370 kHz	5 kW
GREAT BEND	KCKT	TV	CH. 2	100 kW
HAYS	KAYS	AM	1400 kHz	1 kW
HUTCHINSON	KWBW	AM	1450 kHz	1 kW
PRATT	KWNS	AM	1290 kHz	5 kW
RUSSELL	KRSL	FM	95.9 mHz	3 kW
SCOTT CITY	KFLA	FM	94.5 mHz	100 kW

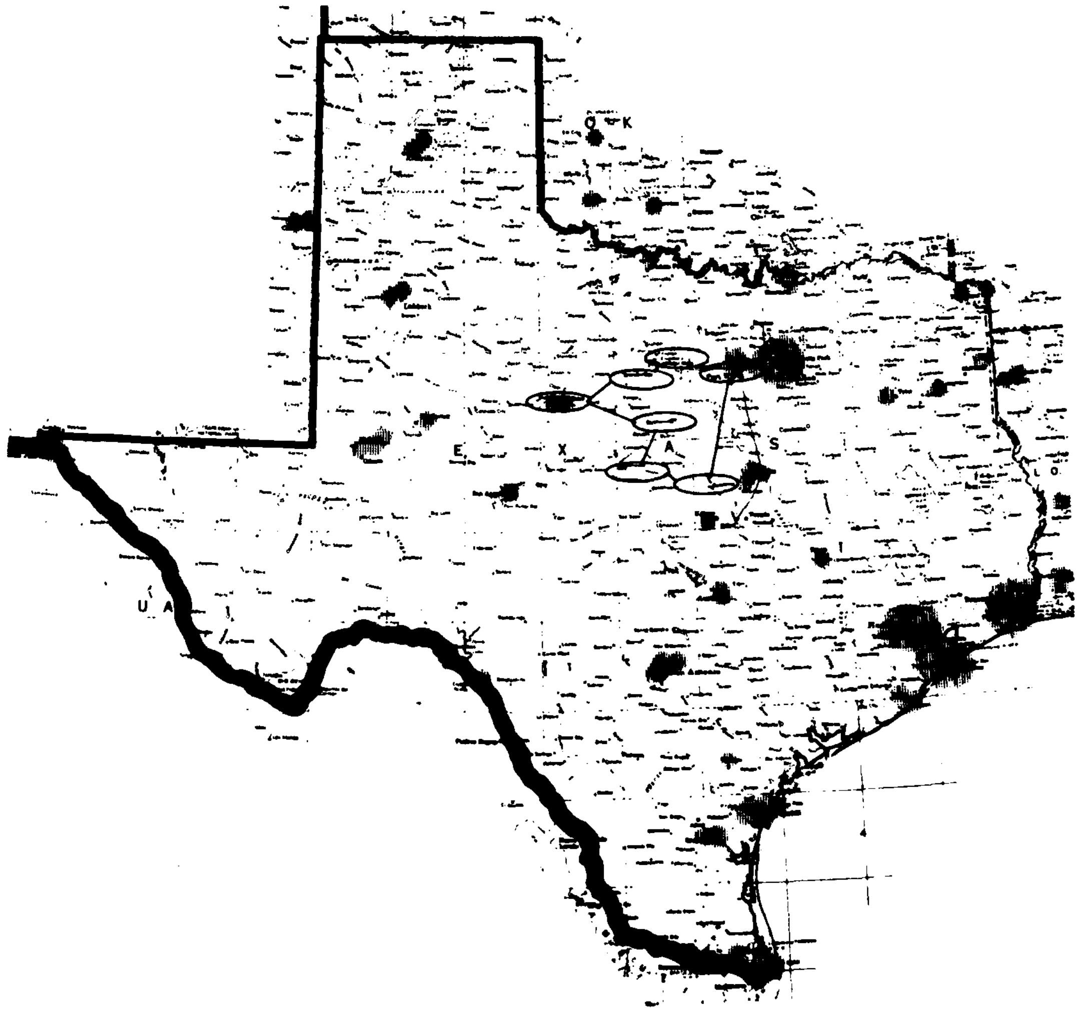
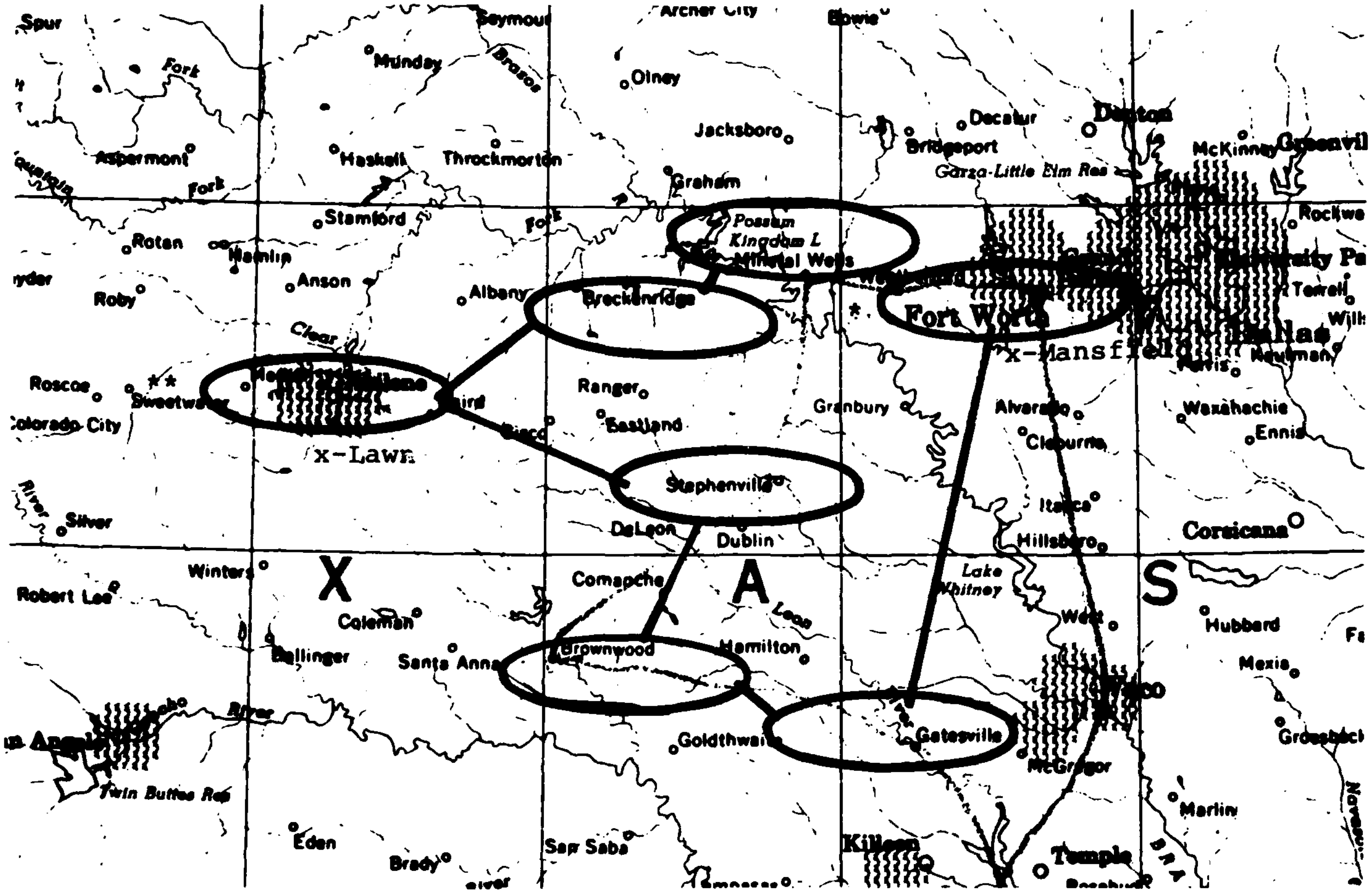


Figure B-13. Transmit Zone 11 - Texas



*Station actually located in Mansfield, Texas
**Station actually located Near Lawn, Texas

Figure B-14. Blown-Up Transmit Zone 11 - Texas

Table B-11. STATE: TEXAS ZONE: 11

CITY	CALL	MODE	FREQ.	OUTPUT POWER
ABILENE (Lawn)	KRBC	TV	CH. 9	31.6 KW
BRECKENBRIDGE	KSTB	AM	1430 kHz	1 kW
BROWNWOOD	KOXE	FM	101.5 MHz	100 kW
MANSFIELD	WBAP	AM	820 kHz	50 kW
GATESVILLE	KMCS	FM	98.3 mHz	3 kW
MINERAL WELLS	KORC	AM	1140 kHz	.25 kW
STEPHENVILLE	KWWM	FM	*	100 KW

* Unknown - to be assigned

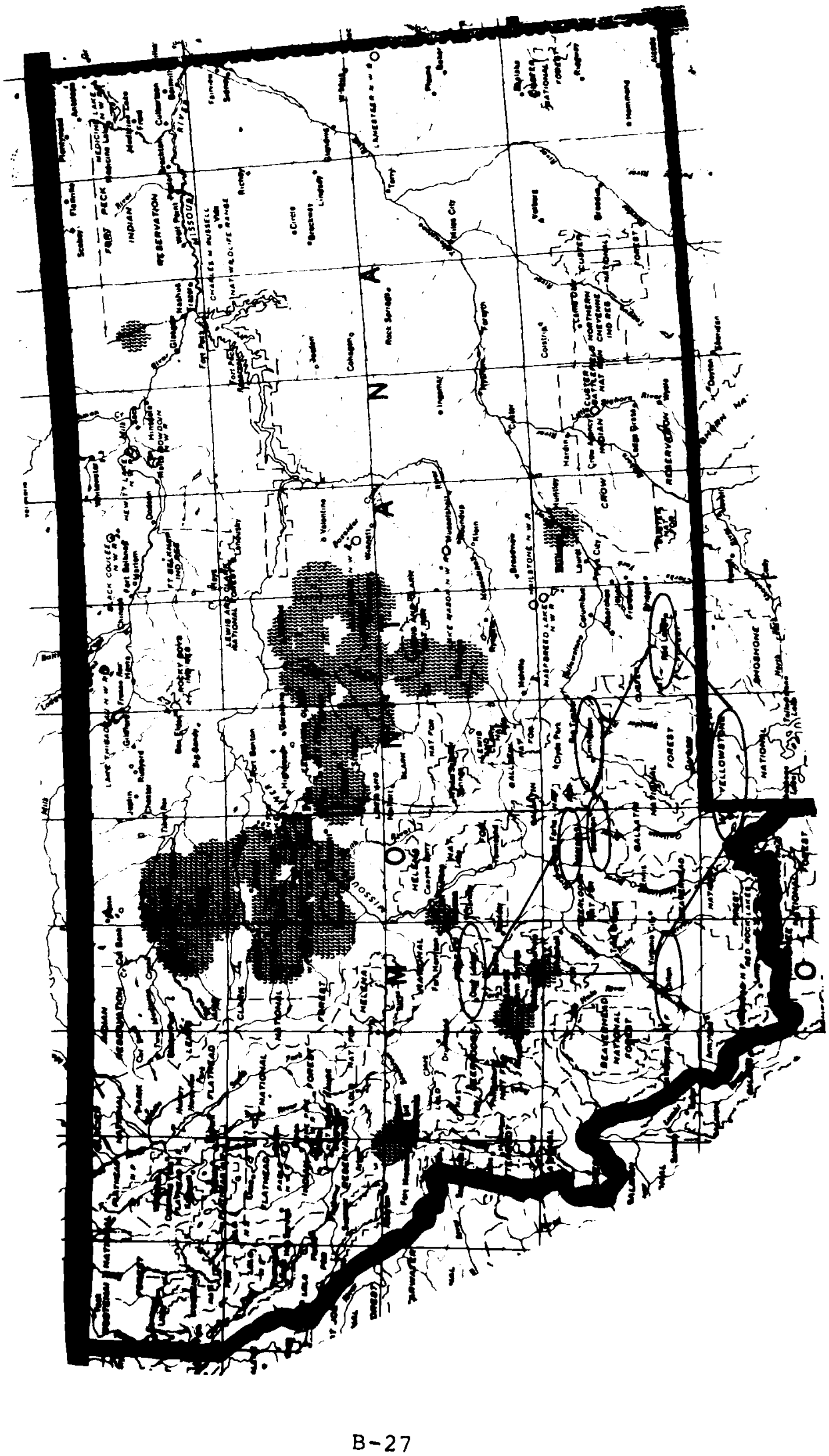


Figure B-15. Transmit Zone 12 - Montana

Table B-12. STATE: MONTANA ZONE: 12

CITY	CALL	MODE	FREQ.	OUTPUT POWER
BELGRADE	KGVW	AM	630 kHz	1 kW
BOZEMAN	KBOZ	AM	1090 kHz	5 kW
DEER LODGE	KDRG	AM	1400 kHz	1 kW
DILLON	KDRM	AM	1490 kHz	1 kW
LIVINGSTON	KPRK	AM	1340 kHz	1 kW
RED LODGE	KRBN	AM	1450 kHz	1 kW
WEST YELLOWSTONE	KWYS	AM	920 kHz	1 kW

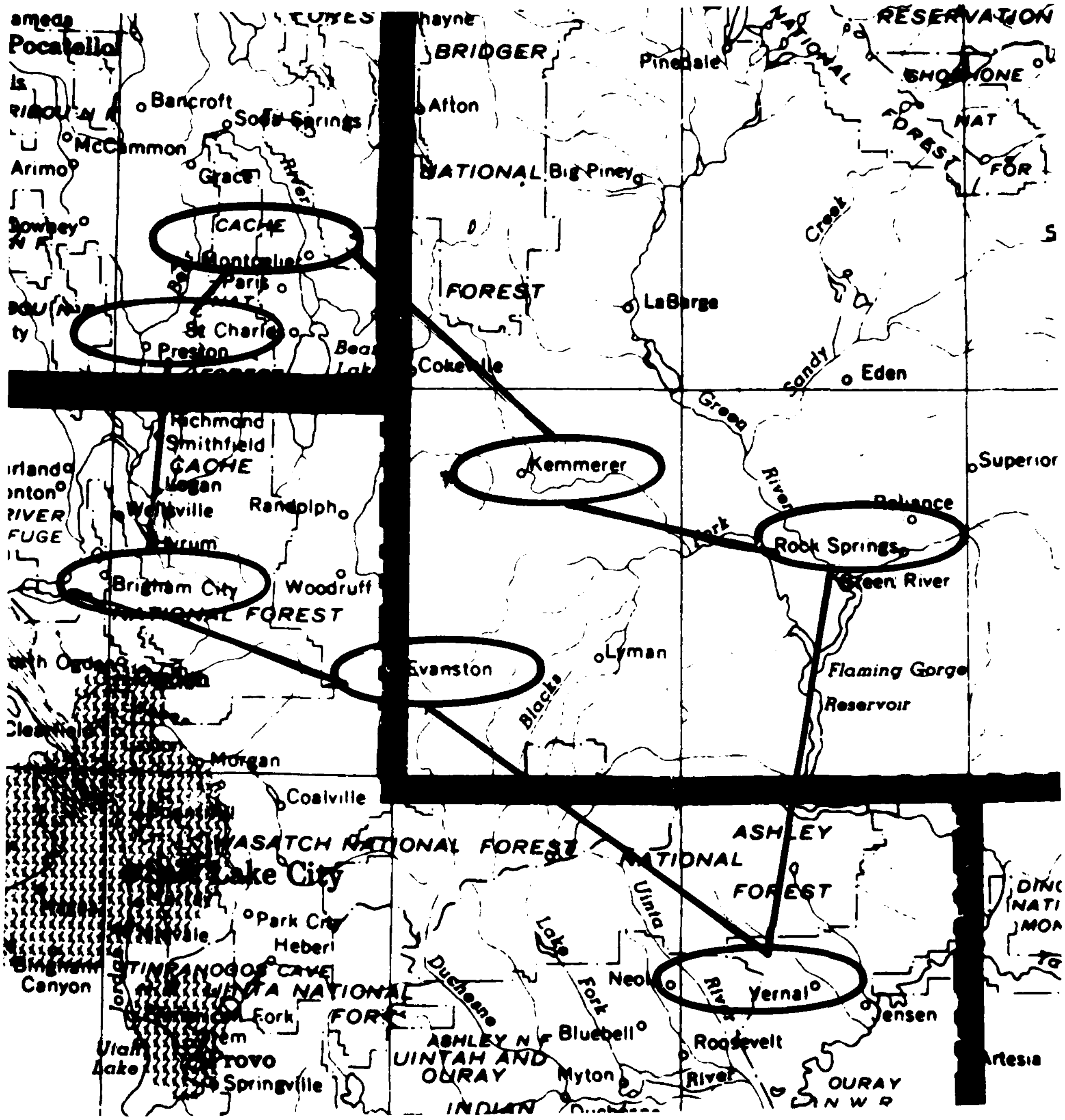


Figure B-16. Transmit Zone 13 - Idaho, Utah, Wyoming

Table B-13. STATE: IDAHO/UTAH/WYOMING ZONE: 13

CITY	CALL	MODE	FREQ.	OUTPUT POWER
MONTPELIER, ID	KVSI	AM	1450 kHz	1 kW
PRESTON, ID	KPST	AM	1340 kHz	1 kW
BRIGHAM CITY, UT	KBUH	AM	800 kHz	.25 kW
VERNAL, UT	KVEL	AM	920 kHz	5 kW
EVANSTON, WY	KEVA	AM	1240 kHz	1 kW
KEMMERER, WY	KMER	AM	950 kHz	5 kW
ROCK SPRINGS, WY	KRKK	AM	1360 kHz	1 kW

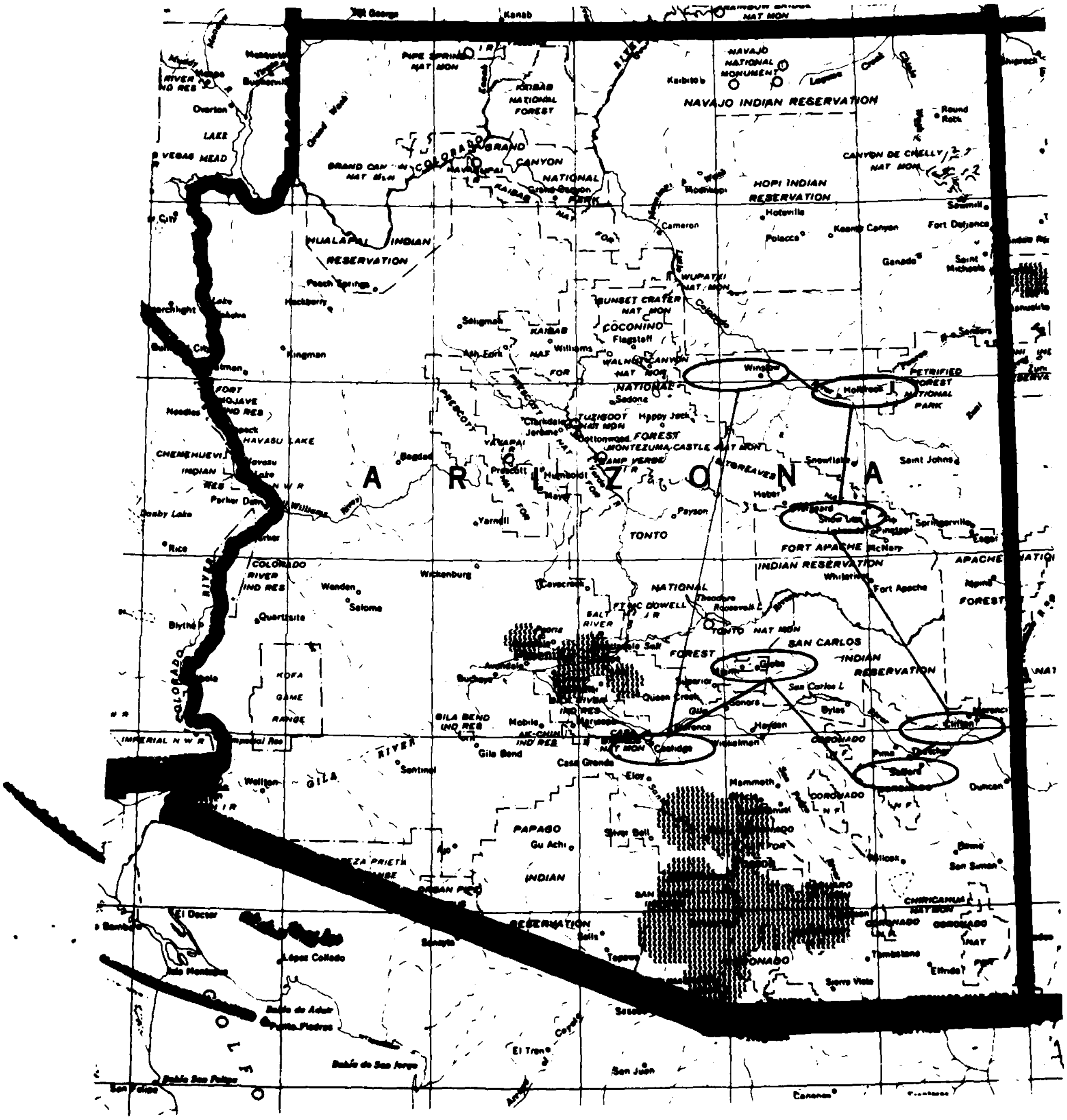


Figure B-17. Transmit Zone 14 - Arizona

Table B-14. STATE: ARIZONA ZONE: 14

CITY	CALL	MODE	FREQ.	OUTPUT POWER
CLIFTON	KCUZ	AM	1490 kHz	1 kW
COOLIDGE	KCKY	AM	1150 kHz	1 kW
GLOBE	KPPR	AM	1240 kHz	1 kW
HOLBROOK	KDJI	AM	1270 kHz	5 kW
SAFFORD	KATO	AM	1230 kHz	1 kW
SHOW LOW	KVWM	AM	970 kHz	5 kW
WINSLOW	KINO	AM	1230 kHz	1 kW

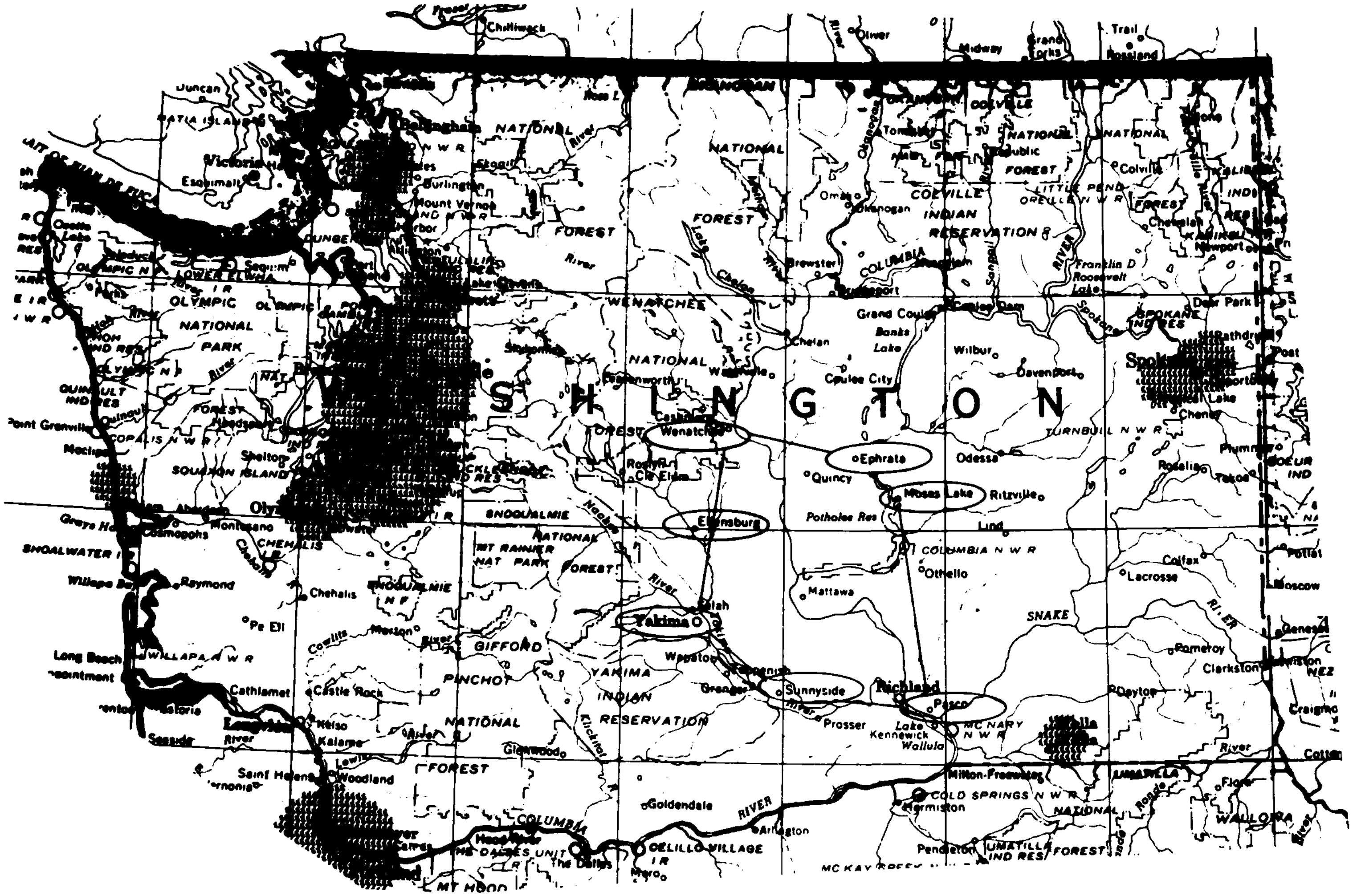


Figure B-18. Transmit Zone 15 - Washington

Table B-15. STATE: WASHINGTON ZONE: 15

CITY	CALL	MODE	FREQ.	OUTPUT POWER
ELLENSBURG	KXLE	AM	1240 kHz	1 kW
EPHRATA	KULE	AM	730 kHz	1 kW
MOSES LAKE	KWIQ	AM	1260 kHz	1 kW
PASCO	KORD	AM	910 kHz	1 kW
SUNNYSIDE	KREW	AM	1230 kHz	1 kW
WENATCHEE	KUEN	AM	900 kHz	1 kW
YAKIMA	KUTI	AM	980 kHz	5 kW

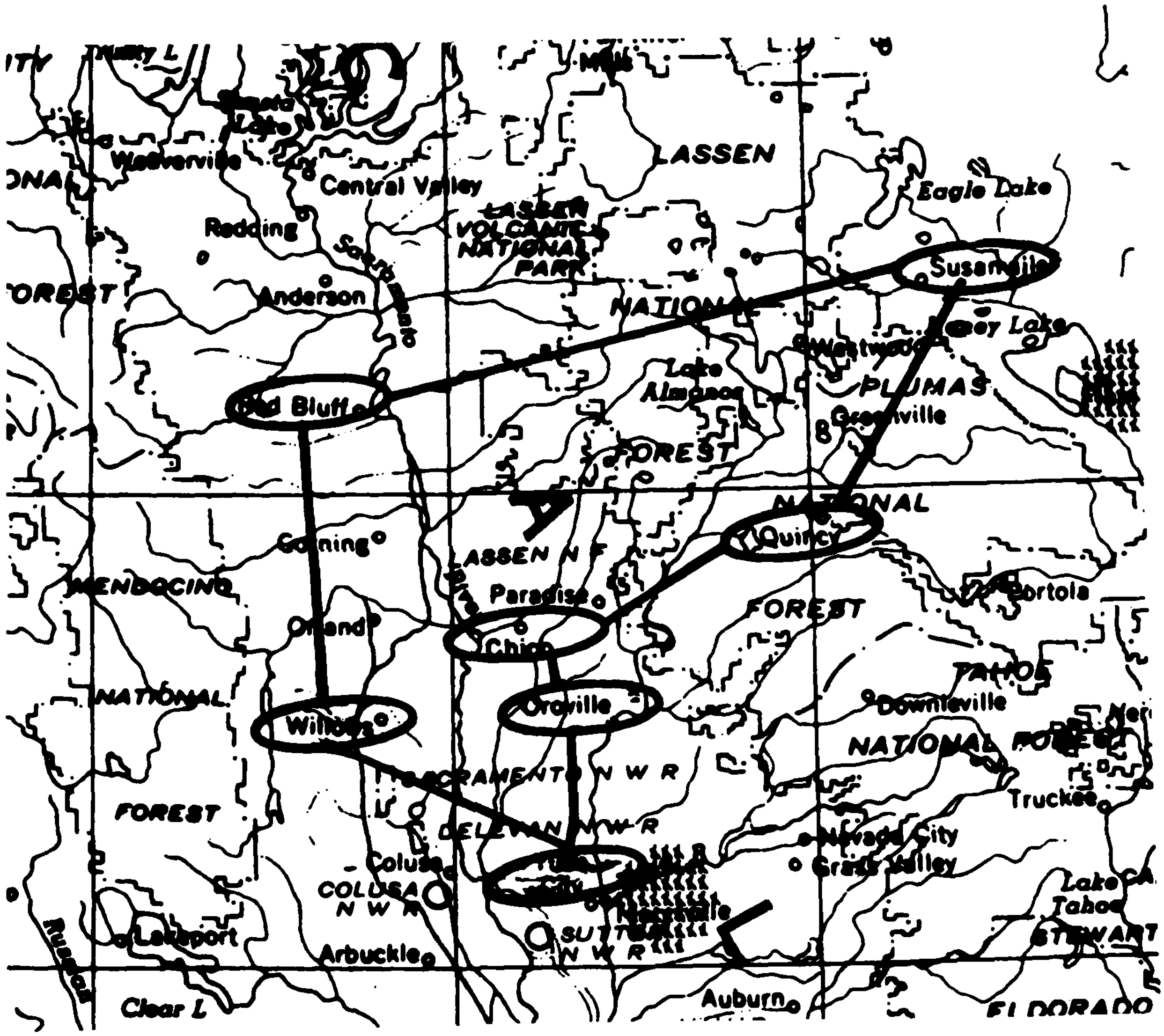


Figure B-19. Transmit Zone 16 - Northern California

Table B-16. STATE: NORTHERN CALIF ZONE: 16

CITY	CALL	MODE	FREQ.	OUTPUT POWER
CHICO	KPAY	AM	1060 kHz	10 kW
OROVILLE	KORV	AM	1340 kHz	1 kW
QUINCY	KPCO	AM	1370 kHz	.5 kW
RED BLUFF	KBLF	AM	1490 kHz	1 kW
SUSANVILLE	KSUE	AM	1240 kHz	1 kW
WILLOWS	KIQS	AM	1560 kHz	.25 kW
YUBA CITY	KUBA	AM	1600 kHz	5 kW

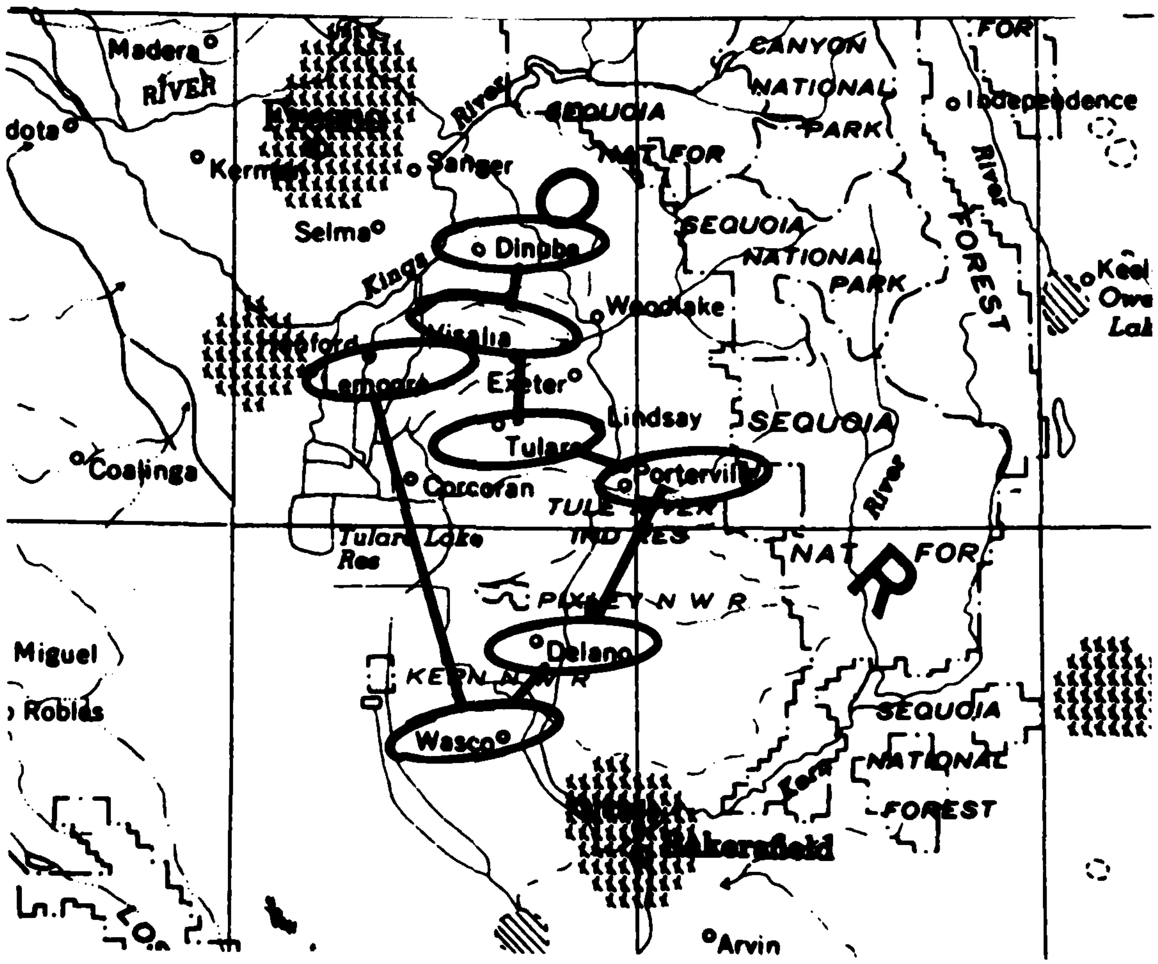


Figure B-20. Transmit Zone 17 - Southern California.

Table B-17. STATE: SOUTHERN CALIF ZONE: 17

CITY	CALL	MODE	FREQ.	OUTPUT POWEF
DELANO	KCHJ	AM	1010 kHz	5 kW
DINUBA	KRDU	AM	1130 kHz	1 kW
LEMOORE	KLAN	AM	1320 kHz	1 kW
PORTERVILLE	KTIP	AM	1450 kHz	1 kW
TULARE	KCOK	AM	1270 kHz	5 kW
VISALIA	KONG	AM	1400 kHz	1 kW
WASCO	KWSO	AM	1050 kHz	1 kW

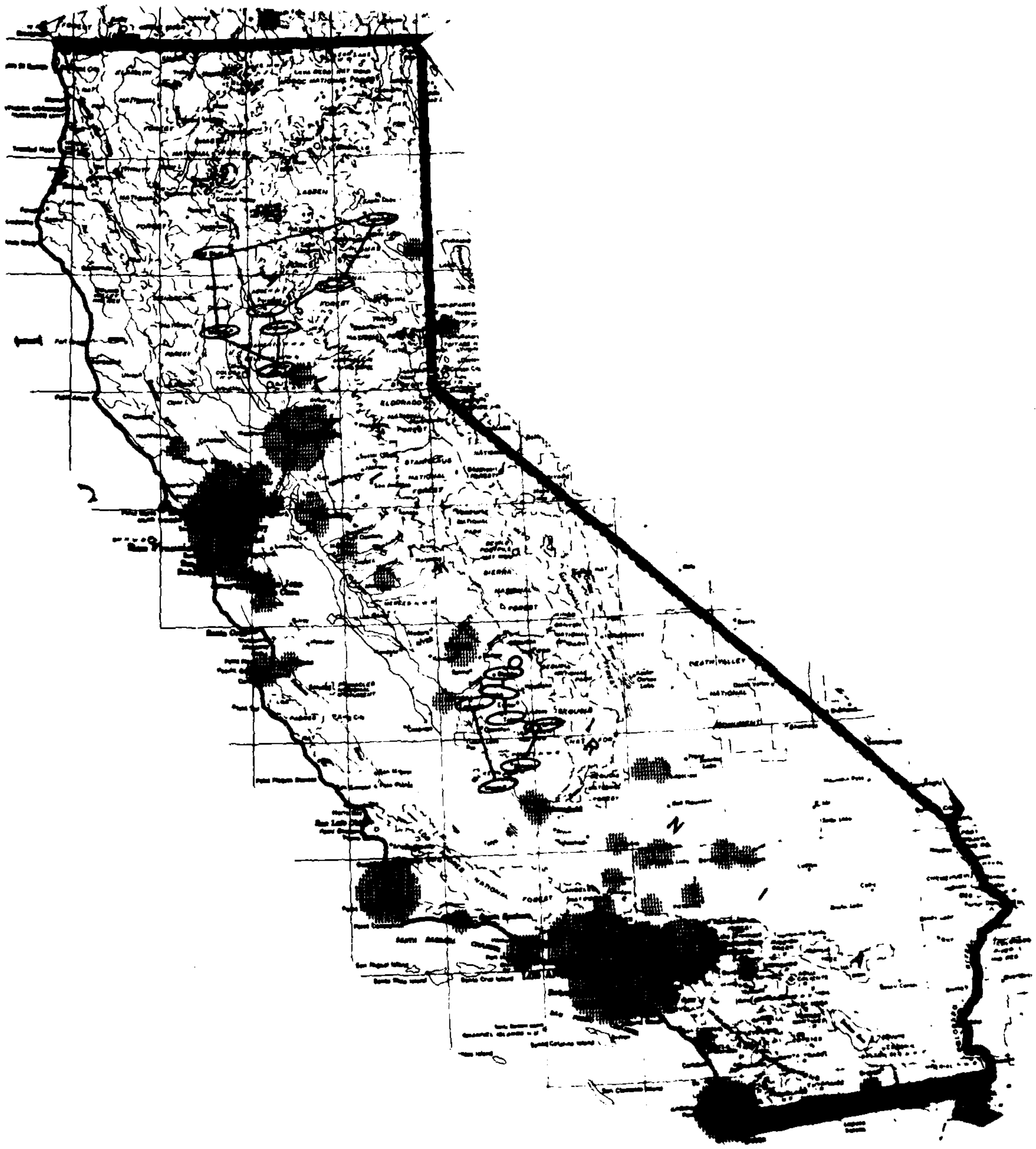


Figure B-21. Transmit Zones 16 and 17 - California.

AD-A092 986 COMPUTER SCIENCES CORP FALLS CHURCH VA F/6 15/3
MOBILE LOW FREQUENCY WARNING SYSTEM FEASIBILITY ANALYSIS.(U)
NOV 80 R R BECK, C D BETHEL, C R DRISCOLL DCPA01-79-C-0264
UNCLASSIFIED CSC/SD-80/3738 NL

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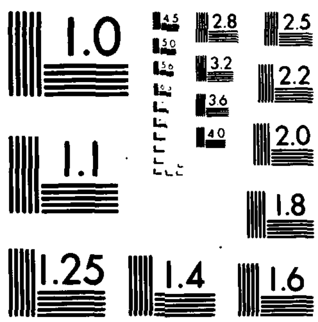


MICROCOPY RESOLUTION TEST CHART

APPENDIX C

LFMWS
PRELIMINARY
PERFORMANCE SPECIFICATION

APPENDIX C - LFMWS PRELIMINARY PERFORMANCE SPECIFICATION

C.1 SYSTEM DESCRIPTION

The Federal Emergency Management Agency (FEMA), has a requirement for a survivable national warning system to warn federal, state, and local officials and the public of an actual or impending attack on the country, of natural or manmade disaster and of related information and instructions prior to, during, and after the event.

The technical and economic feasibility of a low frequency mobile warning system (LFMWS) has been analyzed. The feasibility of multiple low frequency transmitters with mobility, utilizing multiple commercial broadcast station antennas and towers modified as low frequency antennas has been demonstrated. The system to provide this capability consists of the following five major subsystems.

1. The broadcast stations
2. The mobile transmitter units (MUs)
3. The receivers
4. The training, supply and repair facilities
5. Long haul survivable links from the National Warning Centers to the MUs.

This specification covers the first four. The long haul links are the subject of a separate analysis, but this specification covers the interface at the MUs, assuming those links will be available.

The LFMWS depends on mobility and redundancy for survival and is configured into 17 transmit zones and propagation areas to cover the 48 contiguous states.

C.1.1 Transmit Zones

The LFMWS includes the establishment of multiple "transmit zones" across the United States. The term transmit zone is used to identify a general area where 4 to 7 broadcast antenna facilities are located that support a team of two mobile LF transmitter units. This zone is approximately 50 miles in diameter.

Figure C-1 is a typical transmit zone configuration. The antenna facilities are existing AM, FM, or TV broadcast transmitting stations which have been adapted for combined LF and broadcast transmission. The LF transmission is accomplished by ground wave propagation. Since this type of propagation is minimally affected by nuclear effects, both pre-attack and post-attack communications can be provided.

C.1.2 Propagation Areas

Propagation area is the term used to describe a much larger area that is covered by the signal propagated from any of the antennas in a transmit zone. The field intensity of the outer edge of the defined propagation area is 350 microvolts per meter ($\mu V/m$). To provide complete CONUS coverage the propagation areas will overlap. Figure C-2 is a map of propagation areas around transmit zones.

Survivability of the LFMWS is enhanced by the use of multiple mobile LF transmitters and redundant antenna stations, located outside high risk target areas, when possible.

C.1.3 Operations Summary

One of the mobile transmitter units in the transmit area is always in an operating mode. The other mobile unit would be at, or enroute to, another antenna site. The standby, or moving mobile unit, monitors the LF transmission from the operating station. In the event that the operating station becomes inoperative, the standby unit assumes responsibility for the LF transmission.

Warning messages are distributed from National Warning Centers to the LF transmitter stations by both telephone and a survivable long-haul radio network. Candidate long-haul communications systems are meteor burst, adaptive HF, and VLF. The long-haul system is the subject of a separate specification.

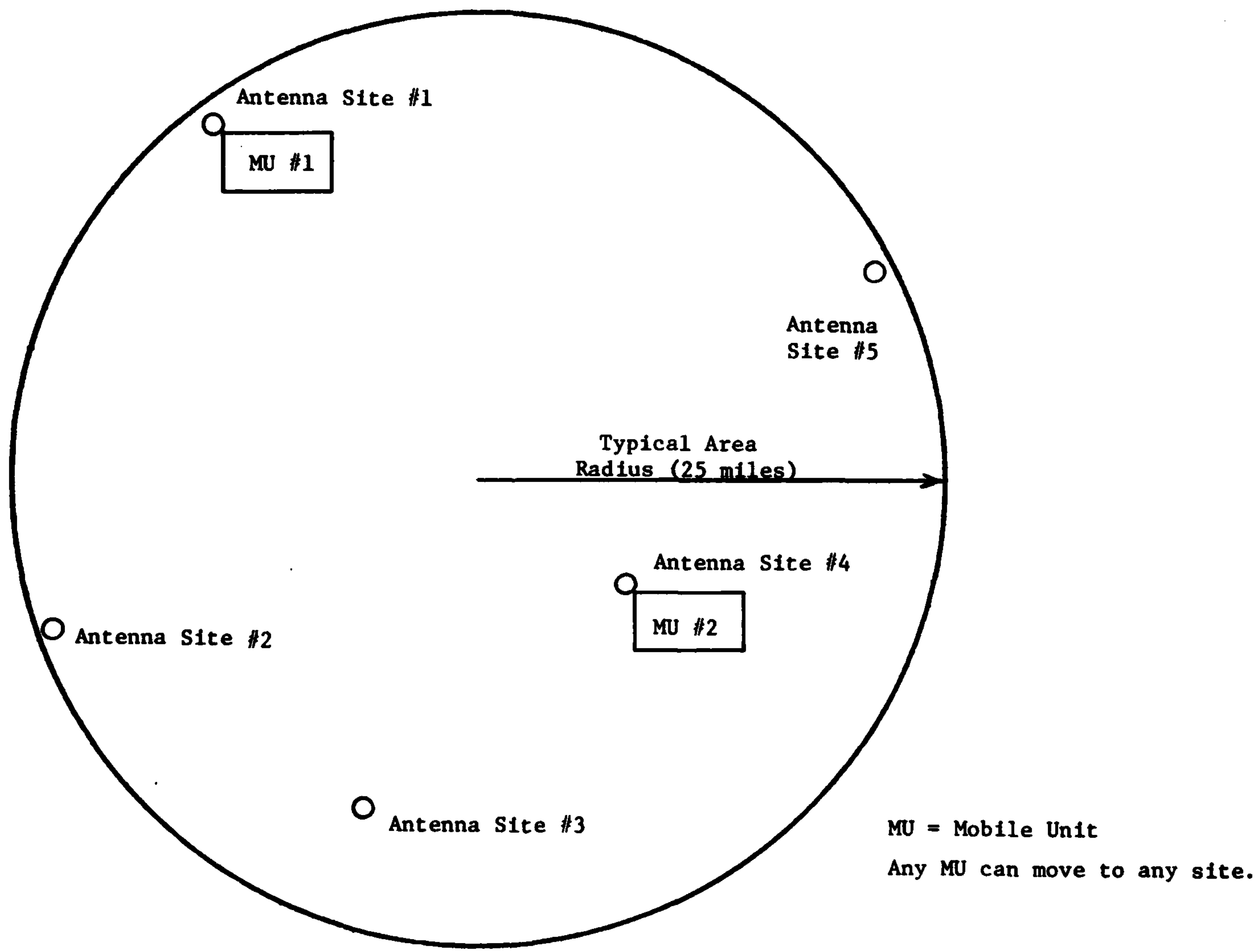


Figure C-1. Typical Transmit Zone U.ilizing Two Mobile Units and Five Antenna Sites

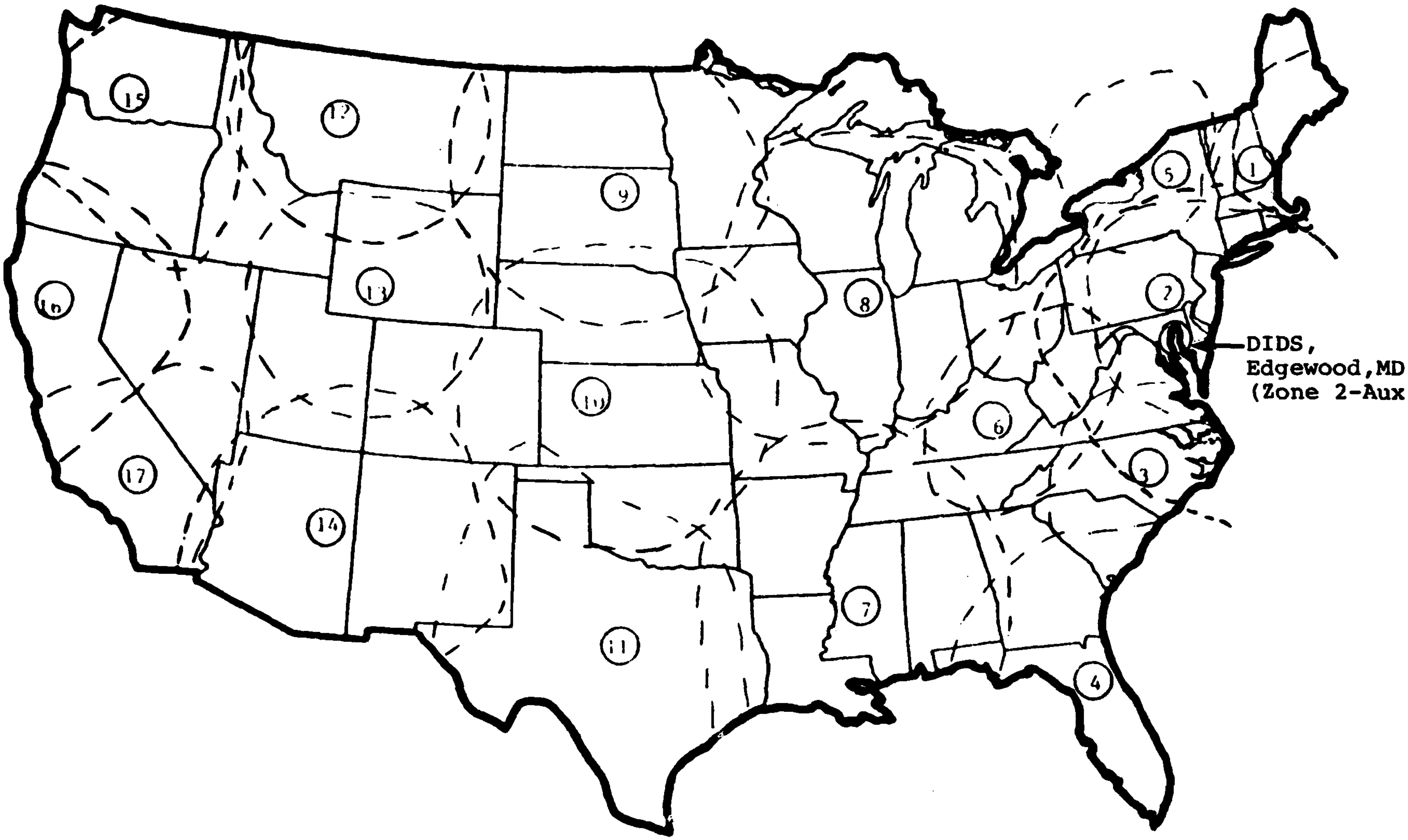


Figure C-2. LF Groundwave Propagation Areas Bordered By 350 $\mu V/m$ Contours For Each Transmit Zone, with 25 KW SSB Transmitter Power (50 KW PEP).

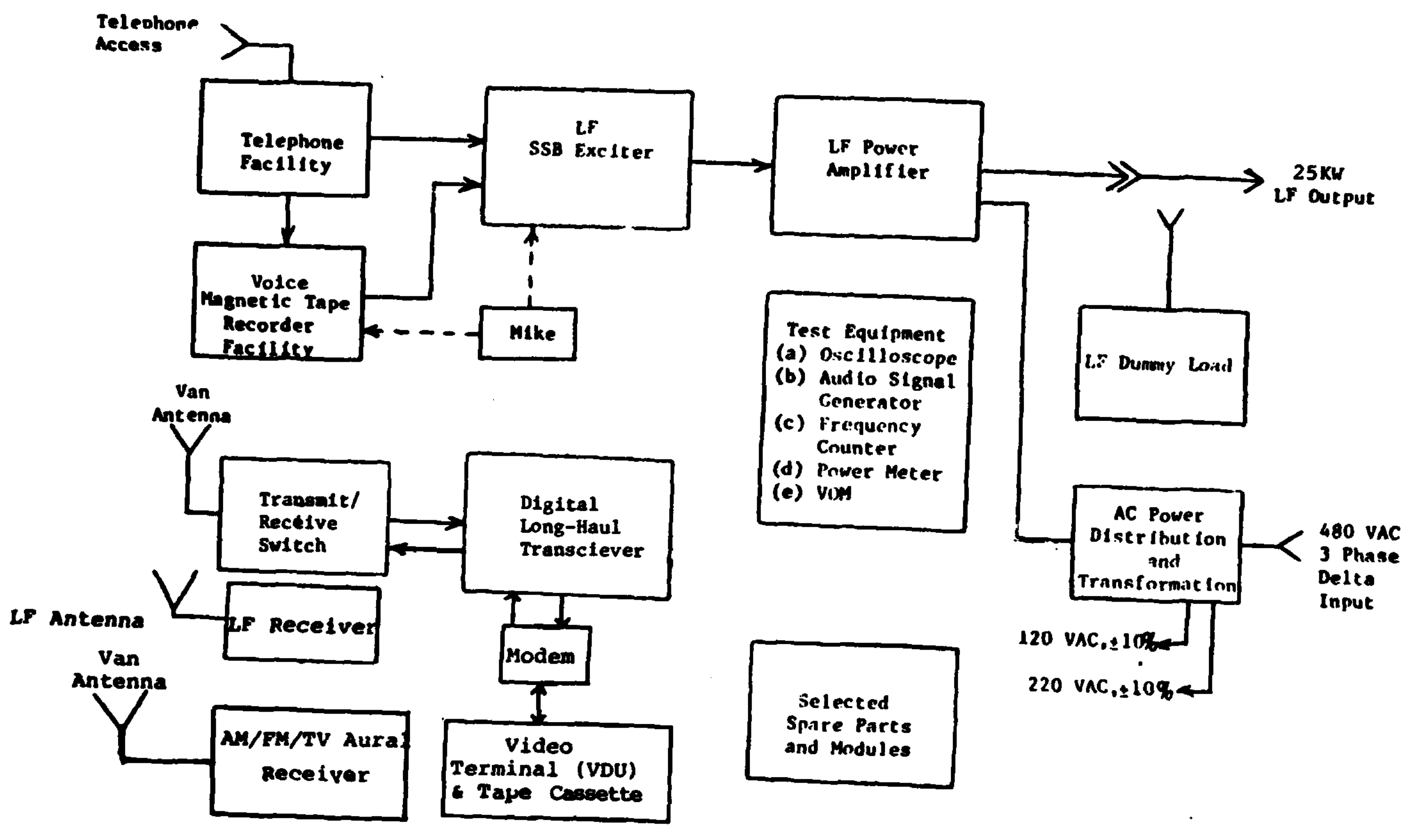


Figure C-3. LF Mobile Transmitter Unit Configuration Diagram

C.2 SYSTEM PERFORMANCE AND CHARACTERISTICS

The LFMWS receives messages from the National Warning Center or an alternate and disseminates these messages to all areas of the country. The inter-communications between the National Warning Center (or alternate) and LFMWS is accomplished by both telephone and survivable radio.

C.2.1 System Communications Performance

The LFMWS provides enough LF transmitters to cover the entire country under worst case conditions (high noise, poor propagation, etc.). The LFMWS is operational on a 24-hour a day and 7-day a week, full-time basis. The system provides a network reliability of 99 percent. The LFMWS provides communication survivability in a nuclear war environment, based on EMP protected redundancy and mobility. To take advantage of the various transmit antenna facilities, periodic moving of transmitter units by human operators is required. Remote control operation of the transmitter mobile units is impractical in light of the mobility requirement. Communications between the mobile units within a zone is required for coordination and self-monitoring purposes. LF receivers in the mobile units serve as a monitor for LF transmission from the other mobile units and also as a means for inter-area communications. AM/FM/TV receivers monitor the broadcast station transmission and status.

A survivable long-haul communication equipment group is required for the passing of National Warning Center messages to transmit zones. Thus, the relay mode is used in a wartime environment, if the telephone system becomes inoperative. Since the long-haul communications system is likely to be bandwidth limited (information rate limited), the use of digital coded signal transmission and pre-recorded emergency messages at mobile unit magnetic tape recorders, is required.

C.2.2 System Frequency Plan

The LF allocation is from 160 to 190 kHz. Single sideband (SSB) modulation is used, requiring 3 kHz for each channel so that 10 channels are available.

Of the 10 SSB channels that are possible in the 30 kHz bandwidth, 2 are set aside for: (1) an all call channel, (2) as an expansion channel, or (3) as an emergency backup channel. Eight channels are used as the standard communication channels. Figure C-4 shows the warning channel plan using eight 3 kHz SSB voice channels for 17 transmit zones. Table C-1 shows the frequency assignments for the 10 channels used in Figure C-4.

Table C-1. Channel Frequency Allocation for a Single Sideband System

Frequency Band Allocation (kHz)	Channel Designation
160 to 163	Channel 1
163 to 166	Channel 2
166 to 169	Channel 3
169 to 172	Channel 4
172 to 175	Channel 5
175 to 178	Channel 6
178 to 181	Channel 7
181 to 184	Channel 8
184 to 187	Channel 9
187 to 190	Channel 10

Channels 3 through 10 would serve as propagation area warning frequencies and channels 1 and 2 serve as spare or all call channels.

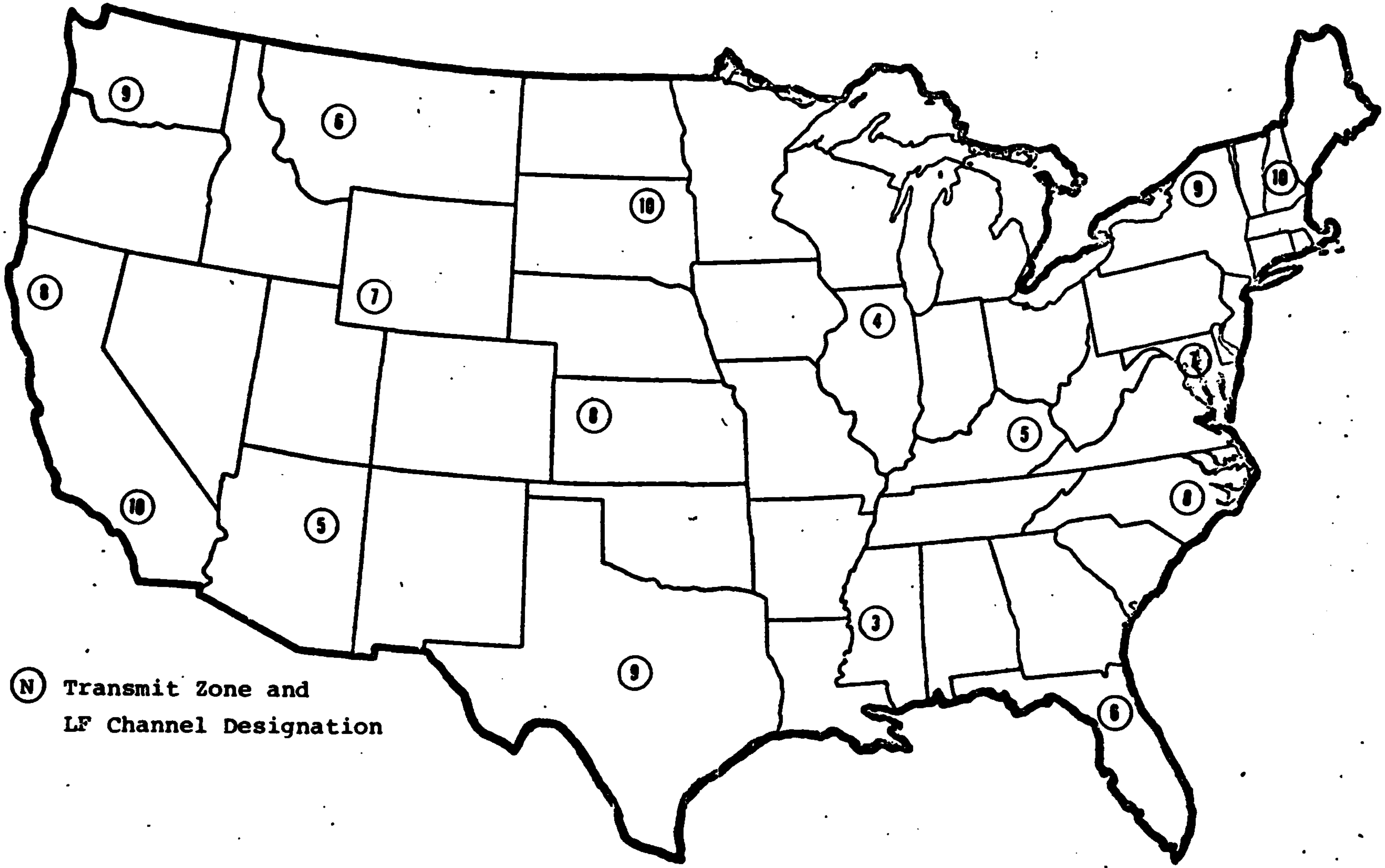


Figure C-4. Channel Allocation For 8 Channels and 17 Transmit Zones

C.2.3 Inter-Communications Interfaces and Characteristics

The primary pre-attack communication means between the National Warning Centers and the LFMWS mobile transmitter unit is the commercial telephone system (primarily ATT). The telephone access will be provided when the mobile units are at the individual broadcast stations. Two telephone line accesses will be provided at each broadcast station. This will allow one phone to be used for area coordination while the other telephone will remain in a non-busy state so that a warning message can be received.

Additionally, a long-haul attack survivable radio communication link from the National Warning Centers to the LFMWS must be provided since the telephone system has limited survivability characteristics.

Mobile units in each transmit zone will receive the National Warning Center communication from either the telephone access or the long-haul radio link. The currently operational mobile unit will be required to disseminate the warning message within seconds of its receipt. The standby mobile unit will monitor the LF transmission from the operational unit. If the warning is not relayed within a specified time, the standby unit will perform the warning task.

The information required to be transferred over the long-haul communication system can be limited if pre-recorded warning messages at the mobile units are selected by the reception of digital coded messages. The use of these short coded messages will allow the use of reliable and adaptable longer range digital communication links. This specification assumes that the long-haul system will function in this manner.

C.3 SYSTEM COMPOSITION

As previously stated, the LFMWS is made up of five major subsystems. Four of these subsystems are covered by this performance specification. The fifth, the long haul system, is specified

separately. The four major subsystems to be specified contain the following component subsystems:

1. The Broadcast Station Subsystem contains
   - Antenna Subsystem
   - Shelter Subsystem
   - Power Subsystem
2. The MU Subsystem contains
   - Transmitter Subsystem
   - Reception Subsystem
   - Long Haul Terminal Subsystem
   - Control Subsystem
   - Test and Status Display Subsystem
   - Power Distribution Subsystem
   - Transporter Subsystem

   and their interfaces
3. The Receiver Subsystem consists of the LF receivers required to receive MU transmissions.
4. The Logistics Subsystem consists of training, supply and repair facilities to support the system.

These major subsystems and their components will be treated in the above order.

C.4 THE BROADCAST STATION SUBSYSTEM

C.4.1 Antenna Subsystem

The LF antenna subsystem consists of standard broadcast (AM) medium frequency (MF) antennas modified for simultaneous use at LF; Frequency Modulation (FM) or television (TV) towers modified to serve as LF vertical antennas; separate LF antennas constructed to utilize the radial systems of AM/MF towers or arrays; separate LF antennas constructed on broadcast station premises for advantages

of co-siting but without any electrical connection to the broadcast antennas; new antennas constructed at new broadcast station sites, optimized for both the broadcast and LFMWS requirements. In all cases the resultant LF antenna shall have a minimum bandwidth of 3.2 kHz to -3 dB points, and a radiation efficiency of at least 65 percent. Depending on the results of field surveys and detailed system design, one of the following methods shall be applied at each broadcast station.

C.4.1.1 Standard Broadcast Series Fed Insulated Tower

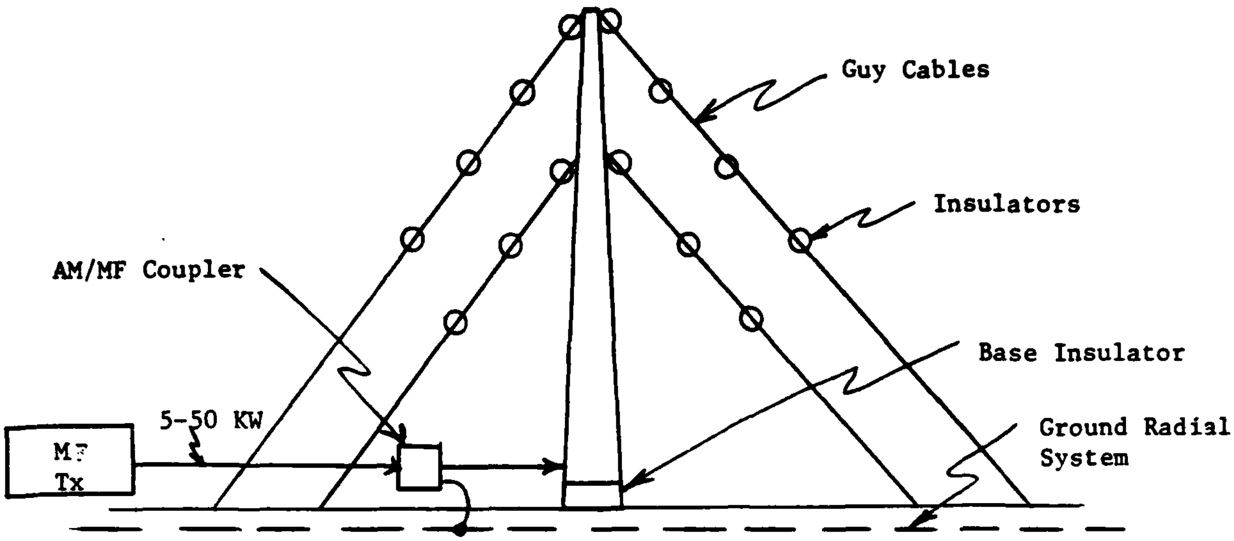
Figure C-5 portrays an unmodified tower antenna of this type and the possible modifications to it to meet bandwidth, efficiency and peak voltage requirements of the LF transmitter. For an existing tower not to require base and guy insulator modifications, it must be insulated for a peak feed point voltage of 52 kilovolts. Peak power to the antenna shall be 50 kW in the 160-190 kHz band.

Towers of this type to be modified for simultaneous use at LF shall have a physical height of between 380 and 760 feet (116 to 232 meters) with modifications applied as in Table C-2, in addition to insulation modifications discussed above.

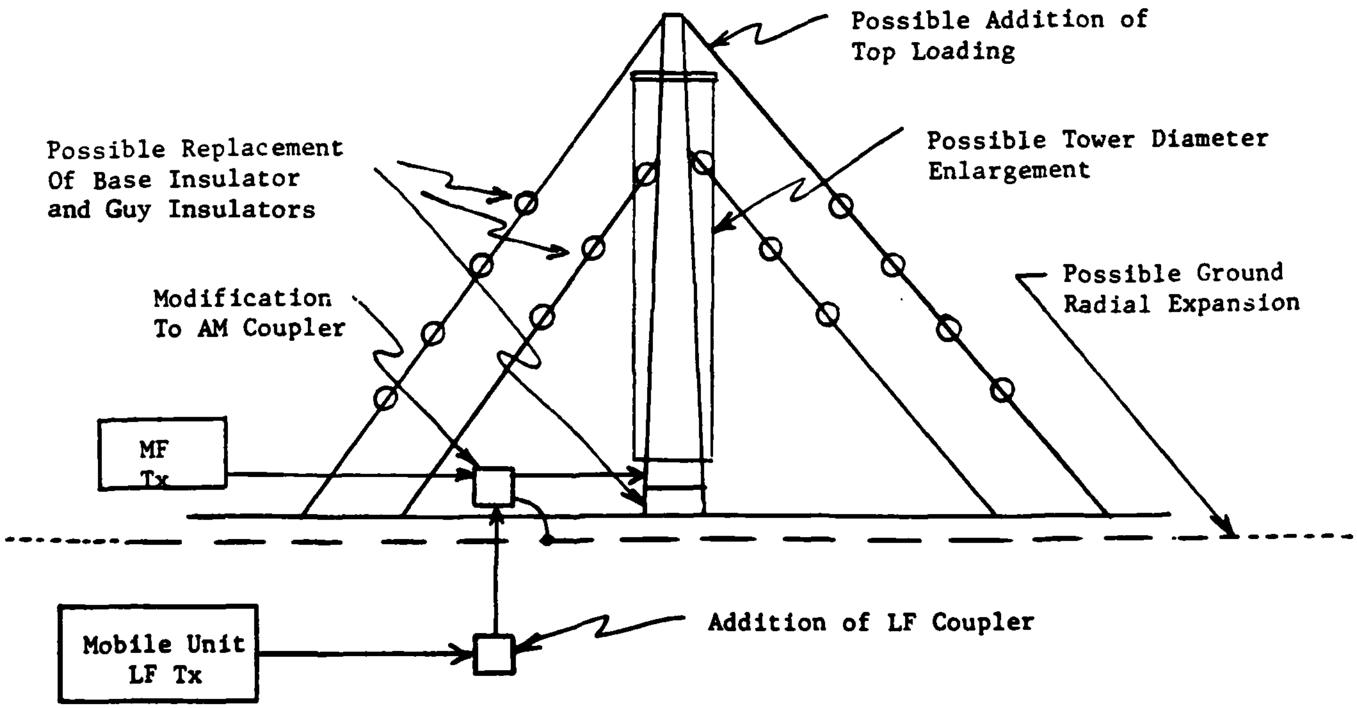
Table C-2. Series Feed Tower Modifications

Tower Height		Add Top Loading	Increase Cross Section	None
Feet	Meters			
380-475	116-145	X	X	
475-570	145-174		X	
570-760	174-232			X

The antenna coupling unit for the MF transmitter to the antenna shall be modified to provide a proper matching to the antenna at both the MF and LF simultaneously. Band stop filters shall be installed to prevent feedback between transmitters and



(a) Existing Series Fed Single AM/MF Tower Configuration



(b) AM/MF Tower Modifications for LF Operation

Figure C-5. Conversion Requirements for an Existing Series Fed AM/MF Antenna

the possible generation and reradiation of crossmodulation products. Figure C-6 depicts a possible antenna coupling network for this application.

C.4.1.2 FM/TV Grounded Tower

FM and TV stations use a tower as a support structure for side or top mounted antennas. The tower is grounded but does not usually have a ground radial system. The tower, if guyed, has uninsulated guy wires. Some stations use the same tower to broadcast both AM and FM/TV signals. In this case the tower may be insulated or grounded (series driven or shunt driven respectfully) and will have insulated guys. The electrically isolated FM/TV antenna on the tower is fed by a long coaxial cable.

Many FM/TV towers are located in mountainous, rolling, and hilly country on the top of the highest available elevation. These are unsuitable.

FM and TV station towers suitable for LF conversion are:

1. Used for FM or TV only
2. Approximately 380 to 800 feet (122 to 244 meters) tall
3. Located outside city limits on flat land suitable for radial installation, up to 1538 feet (469 meters) in length.

The tower height range of 380 to 800 feet is to limit construction problems and system costs. For towers greater than 800 feet, the cost of installing guy insulators or replacing guy cables with insulated cables is high. These costs, for shorter towers, are lower and the modifications simpler and safer. The shorter towers can be made usable by top loading and diameter enlargement. Figure C-7 portrays modifications required for the use of FM and TV towers as LF antennas.

For towers 475 feet and higher the folded unipole type of shunt feed as in Figure C-7 (b) is specified. A T- or L- matching

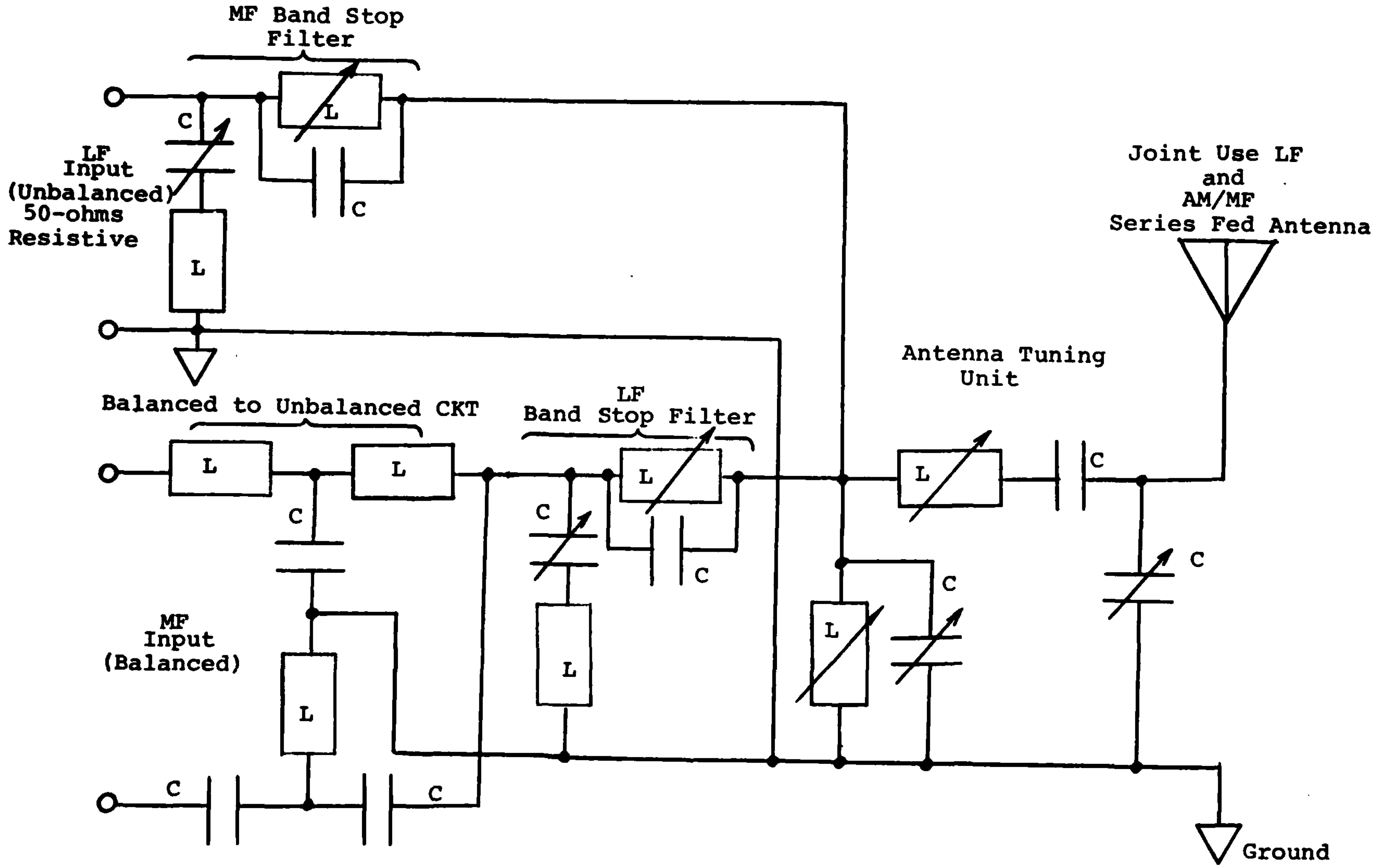


Figure C-6. Antenna Coupler for Feeding an AM Vertical Radiator From an AM/MF Transmitter and an LF Transmitter.

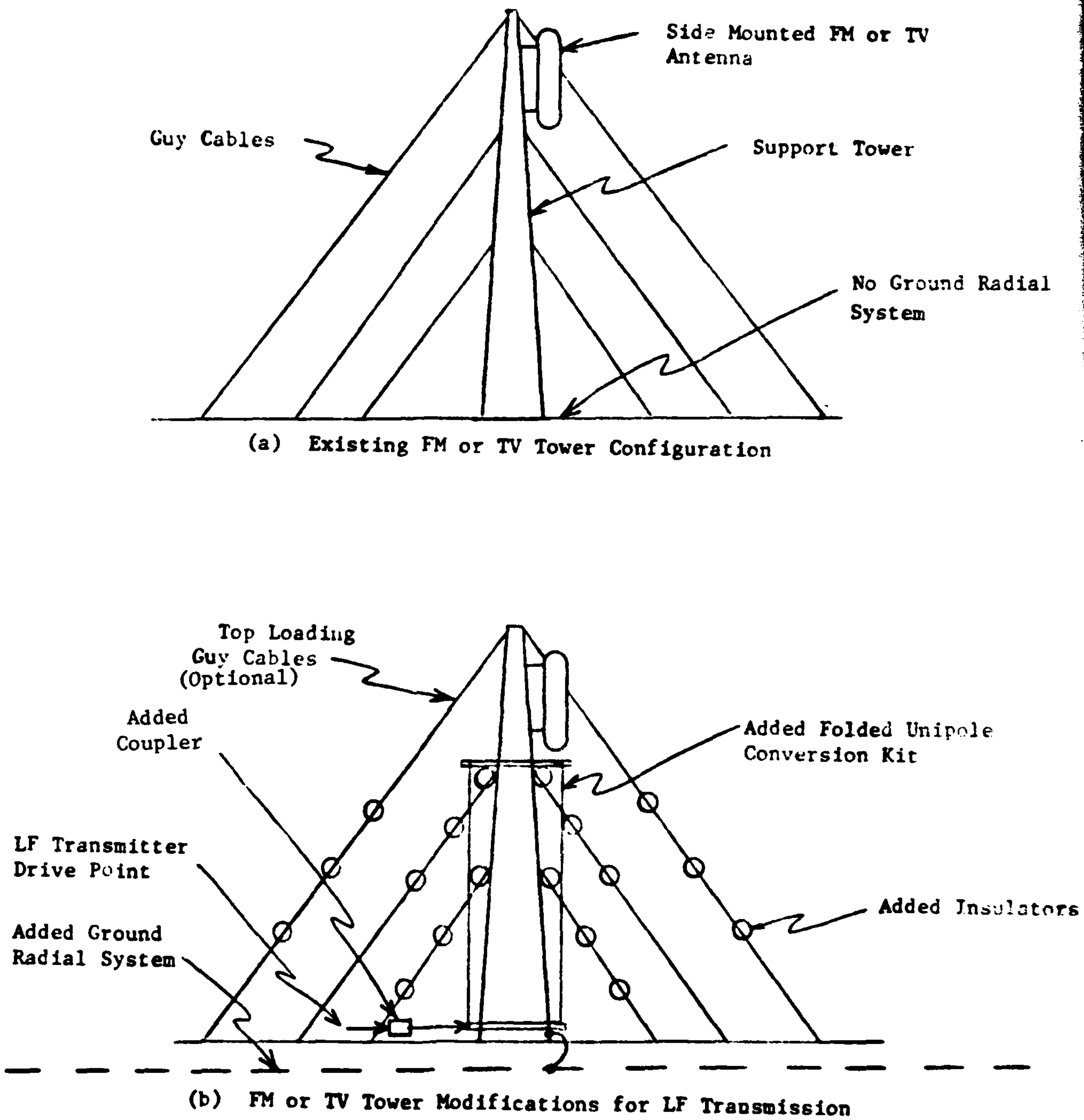


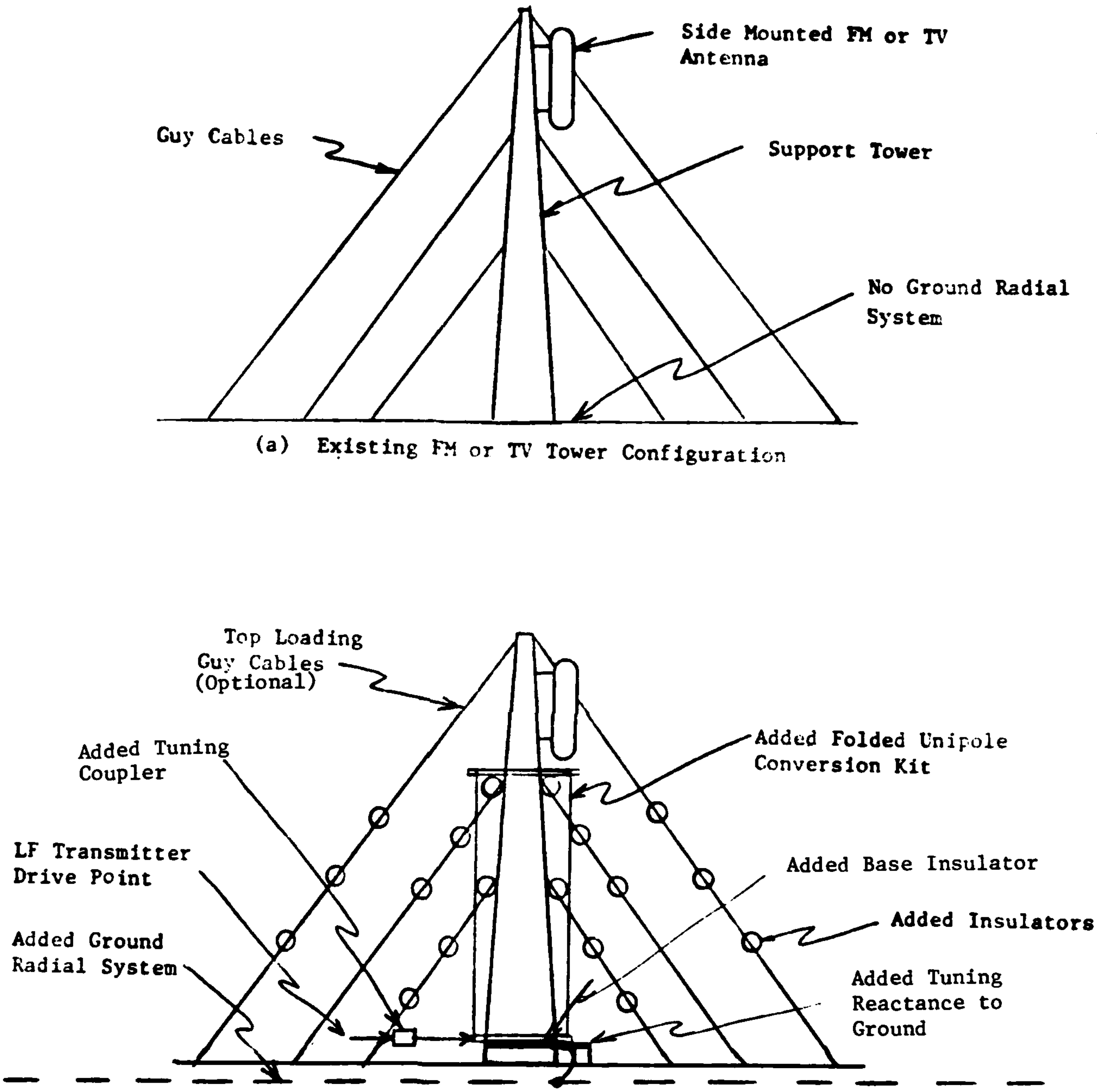
Figure C-7. Conversion Requirements for Existing Tall FM or TV Towers.

network shall be provided to match a 50 ohm coaxial feed from the transmitter to the outside paralleled drop wires of the unipole. The antenna shall meet the bandwidth and efficiency minimums specified in Paragraph C.4.1. If this is not achievable with this configuration, the following alternative shall be employed.

For short towers less than 475 feet high the minimum specifications shall be met by using a shunt folded unipole feed and providing a base insulator. The resulting folded unipole shall be multiple tuned at the feed-point and to ground as depicted in Figure C-8. The tower and some of the drop wires shall be grounded through a reactance, placing the structure at static ground potential to prevent the accumulation of static charge. The other drop wires shall be matched to the 50 ohm coaxial line to the transmitter by means of another network. The number of drop wires fed by the 50 ohm matching coupler and the number of drop wires paralleled with the insulated tower for tuning to ground shall be selected so as to provide maximum bandwidth and efficiency.

C.4.1.3 Separate LF Antennas

An LF multiple fed antenna called a PARAN (Perimeter Array Antenna) and described in a paper entitled "A Short Broadcast Antenna for Restricted Height Locations," by Homer A. Ray, Continental Electronics Mfg. Co., Dallas, Texas, shall be installed around existing AM towers not shorter than 240 feet (73 meters) in height, connected to the common radial system and separately fed by the LF transmitter. The radial system shall be extended to a minimum of 600 feet (183 meters) in all directions from the PARAN towers. The AM tower at the center of the PARAN shall be insulated from and shall support the PARAN top load. The LF PARAN frequency shall not be a sub-harmonic of the AM frequency. The PARAN towers (o) shall be installed with relation to the AM MF towers (x) for single, three, and five tower MF systems, as shown in Figures C-9a and C-9b.



(b) FM or TV Tower Modifications for LF Transmission

Figure C-8. Conversion Requirements for Existing Short FM or TV Towers.

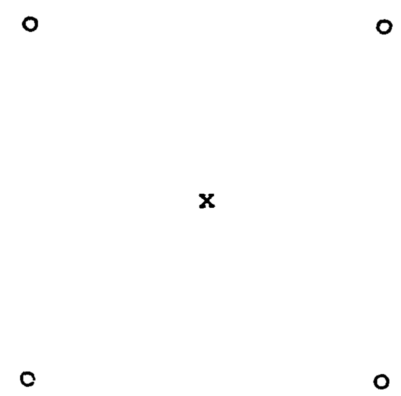


Figure C-9a. PARAN around Single MF Tower

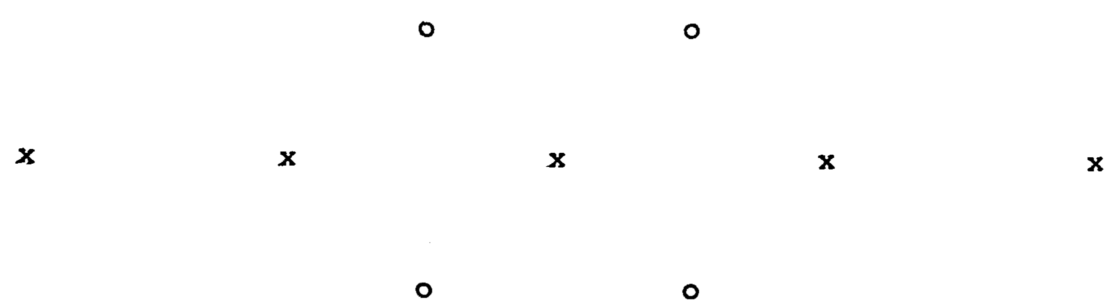


Figure C-9b. PARAN Around Center Tower of 3 or 5 Tower MF In-Line Array

Alternatively, the PARAN shall be installed on the existing land, or land immediately adjacent to a broadcast facility, with its own ground system, taking advantage of the power facilities and shelter installed at the broadcast station. In either configuration the PARAN shall have the following characteristics:

Physical

Elements	4
Height	200 ft (61 meters)
Perimeter	800 ft (244 meters)
Shape	200 ft (61 meters) square

Electrical (at 160 kHz) (worst case)

Efficiency	87%
Coil Reactance	400 ohms
Current (Element)	39 amps
Voltage	15 kV
Power	50 kW
Radiation Resistance	7 ohms
Coil Loss	.5 ohms
Ground Loss	.5 ohms

The above assumes 600 foot (183 meters) radials and good ground conditions.

In areas where icing conditions prevail, the PARAN top-load shall be fitted with pulleys at its four corner tower support points, with cables dropping to counter weights to allow sagging of the top load with the weight of ice.

C.4.1.4 New Antennas for Joint Use at New Sites

In cases where broadcast stations are planning to move to a new location, a joint venture arrangement shall be negotiated to provide the location, space for radials, and size and type of tower to mutually serve the needs of the broadcaster and the LFMWS. This shall apply to both AM , MF stations and to FM/TV stations planning such moves and willing to cooperate. The new tower design shall

be jointly accomplished by the broadcast and government consultants. The broadcast station shall be responsible for the costs for its planned move and upgrade, had government participation not been considered. The government shall be responsible for any incremental costs to meet the LFMWS antenna requirements.

C.4.1.5 Interface to the MU Subsystem

In all cases involving the antenna options discussed above, the antenna tuning unit shall be adjacent to the antenna feed point. The antenna tuning unit shall match the antenna to a 50 ohm coaxial feed line to the LF transmitter at the assigned zone frequency, and shall not reduce the system bandwidth below the minimum specified. The 50 ohm coaxial cable shall be buried below the antenna ground radials and shall enter the station fall-out shelter in the vault constructed for the MU, at a location consistent with the positioning of the MU LF transmit antenna output feed. The coaxial cable from the tuning unit shall, when not connected to the MU, be terminated in a 50 ohm non-inductive resistance plug if the antenna is jointly used by an AM/MF broadcast station and the LF tuning unit is part of a network such as depicted in Figure C-6. In all other cases, the coaxial cable when not connected to an MU shall be terminated in a short-circuit plug. The sheath of the coaxial cable shall be bonded to the antenna ground system at the antenna feed-point.

C.4.1.6 Protection From EMP Through Antenna Feed

Provisions for switching the antenna feed point from tuning unit to ground, automatically from a control position, shall be provided when the antenna is not in use for protection against EMP. This control circuit shall also disconnect the transmitter output from the coaxial feedline. In all cases, including combined use of the antenna with an AM/MF broadcaster, this circuit shall not be operable if any transmitter high-voltage circuit is energized.

State of the art methods, including air spark gaps and gas gaps, shall be used to protect capacitors used in the tuning and coupling units. The coaxial cable antenna feed shall be enclosed in ferrous conduit and enter the equipment shield through an EMP vault.

C.4.2 Shelter Subsystem

The shelter subsystem consists of a below-ground reinforced concrete structure. The thickness of concrete plus earth covering, combined with configuration of accesses and the design of ventilating/air-conditioning systems shall provide a protection factor (PF) from fall-out radiation of at least 500. Separate vaults in the shelter shall be provided for a) the emergency generating plant, b) the MU and c) the emergency broadcast station studio and living quarters. These three areas shall have separate accesses. The emergency generator shall be separated from the other areas by a sound-proofed bulk-head. Access shall be provided between the three vaults for operational personnel.

C.4.2.1 Space and Ventilation Requirements

Space requirements are dependent on individual station emergency studio facilities, emergency generator size, and size of the LF MU, and the necessary utilities to support them. The actual size of the shelter and its components shall be determined during detailed system design.

C.4.2.1.1 Access and Egress

Entry ways shall be large enough for the largest piece equipment to enter. In the case of the MU, this will entail a ramp from ground level and swinging type blast door, to protect against over-pressure.

C.4.2.1.2 Ventilation

Provisions shall be made to prevent the build-up of vitiated air to a level hazardous to the occupants. Temperatures in personnel areas should not exceed 70°F (21.1°C).

C.4.2.1.3 Filters

All air drawn from the exterior shall pass through filters which will remove any foreign material and particles. Double filters shall be provided so that replacement can be effected without intake of particles.

C.4.2.1.4 Fresh (Outside) Air

A minimum of 7 cfm (.2 cubic meters) of fresh air per person shall be provided to the emergency studio and living area. A minimum of 3000 cfm (85 cubic meters) of outside air shall be provided for the mobile unit area. Cooling air for the transmitter of 2000 cfm (57 cubic meters) shall be exhausted direct to the outside. The emergency generator area shall be provided with its own filtered outside area intake and shall have its own exhaust duct to the exterior for radiator cooling air. Motor exhaust shall be piped to the outside through the shelter roof.

C.4.2.1.5 Duct Systems

The three main shelter areas shall have separate, independently operated duct systems so that unused areas may be shut down independently.

C.4.2.1.6 Air Conditioning

Air Conditioning shall be required for the emergency studio/ living area.

C.4.2.2 Water Supply and Sanitation

All MU cooling shall be forced filtered air. The emergency plant shall be liquid cooled, but shall be a closed system. Water for personnel consumption and sanitation for up to 30 days shall be available either from storage tanks or a well directly accessible from the shelter without outside exposure of its output.

Garbage and sewage disposal shall be provided for.

C.4.2.3 Communications

Telephone lines for connection to the MU shall terminate in an an EMP vault within the MU and be EMP protected.

The LF transmit antenna coaxial cable and control lines for antenna grounding shall enter the MU vault underground, as described in Paragraphs C.4.1.5 and C.4.1.6.

Feed through connections shall be provided in the roof of the MU vault with internal connectors for antenna cables and external connectors for LF receiver loop antenna, long haul warning circuit and broadcast station monitoring antennas. All of these antenna feeds shall be EMP protected as specified in Paragraph C.4.1.6.

C.4.3 Power Subsystem

Commercial and emergency power feeds with switchover and control circuits and panels shall be provided in the MU vault of the fall-out shelter. Feed lines and controls shall be EMP protected by filters and electrical surge arrestors at the generator and the entry to the MU.

C.4.3.1 Commercial Power

An alternating current (AC) distribution/transformation circuit shall be provided. The AC source shall be 3 phase, 480 VAC, 60 Hz delta or wye connected and capable of supplying the entire mobile unit load.

C.4.3.2 Emergency Generator Power

An emergency diesel/electric generating plant shall be provided in each shelter capable of supplying the power requirements of the mobile transmitting unit, and its associated equipment, and the power requirements of the host commercial station transmitting plant and emergency studio equipment. It is estimated that a 100 KW unit will be adequate in most cases.

C.4.3.3. Power Distribution

Because of the uniqueness of each transmitter site (high/low power, colocated/remote broadcast studio, etc), the following shall be provided:

1. Sufficient power to allow simultaneous, full rated, operation of the host system and LFMWS MU without degradation of either system.
2. Each system shall be individually protected against overload to the power distribution system so as to have no effect on the operation of the other system.

C.4.3.4 Fuel Supply

Sufficient fuel supply shall be stored in an underground tank to allow full load operation of the emergency plant for up to 15 days.

C.5 THE MU SUBSYSTEM

The MU subsystem is made up of the transmitter subsystem, the reception subsystem, the long haul terminal subsystem, the control subsystem, the test and status display subsystem, the power distribution system, the transporter subsystem, and their interfaces. Figure C-3, is representative of the MU subsystem, and should be referred to when considering this specification.

C.5.1 The Transmitter Subsystem

The transmitter subsystem shall provide the capability to transmit LF signals (160 to 190 kHz) in the single-sideband, suppressed carrier mode (A3J). The transmitter shall operate in the single-sideband (upper sideband only) mode with 25kW average or 50 kW Peak Envelope Power (PEP) output. It shall be tuned to operate on one of ten 3 kHz channels between 160 and 190 kHz. The operating frequency shall be crystal oscillator controlled. The transmitter shall be capable of continuous 24 hour/7 day per week operation for periods of 30 days or more, at an average power output of 25 kW.

C.5.1.1 Frequency Stability

The transmitter shall maintain channel frequency within $\pm$ 20 Hz over an ambient temperature range of 0 to 50 degrees centigrade.

C.5.1.2 Intermodulation Distortion

Intermodulation distortion products shall be 35 dB below the level of either tone of a standard two-tone test with levels set for specified output.

C.5.1.3 Spurious Emissions

Spurious emissions shall be at least 60 dB below specified power output.

C.5.1.4 Harmonic Radiation

Harmonic radiation shall be at least 30 dB below specified power output.

C.5.1.5 Suppressed Carrier Level

The suppressed carrier level shall be at least 40 dB below the output level of a single tone modulating the transmitter to specified power output.

C.5.1.6 Audio Input

The audio interface shall provide a 600 ohm termination for input from magnetic tape, telephone line or a microphone. The frequency response shall be $\pm$ 1.5 dB over the frequency range of 250 Hz to 3250 Hz. The return loss shall be a minimum of 20 dB against the nominal impedance over the frequency range. The normal input power level shall be -20 dbm to +10 dbm for full output.

C.5.1.7 Audio Bandwidth

The audio bandwidth shall be from 250 Hz to 3250 Hz (3.0 kHz). The maximum variation shall be 3 dB.

C.5.1.8 Tone Transmission

The transmitter shall accept tone generator/encoder signals of a minimum of three separate audio tones for receiver muting/demuting operation, over a control line.

C.5.1.9 Output Impedance

The output impedance of the transmitter shall be 50 ohms nominal, unbalanced. Operation with a VSWR of up to 2 or 1 shall be possible, without reduction in power output or damage to any component.

C.5.1.10 Power Requirements

The transmitter shall operate from 480 volts AC, three phase, 60 cps.

C.5.1.11 Electromagnetic Pulse (EMP) Protection

The transmitter shall be provided EMP protection within "state of the art" technology, as specified in paragraphs C.4.1.6, C.4.3 and C.5.7.1.

C.5.1.12 Built in Test Equipment (BITE)

Built in test equipment features shall be incorporated to the maximum extent possible. This is to allow status and performance determination to be performed by an operator. These BITE features shall allow a skilled operator to identify, locate, and replace malfunctioning components.

C.5.1.13 Modular Design

The transmitter shall be of modular construction to facilitate rapid replacement of failed components.

C.5.1.14 Shock and Vibration

The transmitter shall be provided with shock and vibration absorbing devices to allow protection during transportation

periodically (approximately monthly) in a shelter or van over primary and secondary roads for distances of up to 100 miles, without disassembly of components, special bracing or reinforcement.

C.5.1.15 Power Amplifier Cooling

The transmitter shall be air-cooled by filtered forced air and shall require not more than 2000 cfm under specified environmental conditions.

C.5.1.16 Operating Humidity

The transmitter shall operate at full power under conditions of 0 to 95 percent relative humidity.

C.5.1.17 Altitude

The transmitter shall operate at full power at elevations ranging from sea level to 8000 feet above sea level.

C.5.1.18 Dummy Load

The LF transmitter shall be provided with a dummy load capable of continuous operation at the specified transmitter power output. The dummy load shall be air-cooled and contain its own blower system.

C.5.2 The Reception Subsystem

The reception subsystem of the MU consists of those receiving equipments used for inter-communication between MUs in the zones or between zones and for monitoring host broadcast facilities before and during MU movement operations.

C.5.2.1 The LF Receiver

An LF receiver shall be provided to each MU for the purpose of monitoring the transmissions of the operating MUs while en route between host locations and while standing by at a host location. The LF receiver provided shall be identical to that specified in Paragraph C.6. A feed through mounting for a low frequency

loop antenna shall be fitted to the top of the MU housing with an antenna cable extending inside to the receiver location. It shall be possible to remove the antenna from the mounting so that a jumper may be connected between the MU housing and the feed through on the interior roof of the fall-out shelter. Under this condition the loop antenna shall be mounted on the feed through above the fall-out shelter (see Paragraph C.4.2.3). It shall be possible to mount the loop antenna directly on the receiver for portable use, as required.

C.5.2.2 AM/FM/TV Receiver

A small battery operated tunable receiver shall be provided capable of receiving the standard AM broadcast band, all standard FM broadcast channels and all standard TV VHF sound channels. This receiver shall be fitted with rechargable batteries and a charger and a built in antenna. It shall also be possible to connect an external antenna to this receiver through cables and feed-through fittings on the MU housing and the fall-out shelter roof (see Paragraph C.4.2.3).

C.5.2.3 The Long-Haul Receiver

A receiver shall be supplied as part of the long-haul terminal subsystem specified in Paragraph C.5.3 below.

C.5.3 The Long-Haul Terminal Subsystem

This specification assumes the existance of a survivable long-haul radio system for backing up the wire system to relay commands and coordination data from the warning centers to the LFMWS. On the assumption that the long-haul system specified separately will be a meteor burst communications system (MBCS), the MU shall be fitted with an MBCS antenna and terminal. The MBCS shall function in the VHF band.

C.5.3.1 Long-Haul Antenna

A parasitic VHF array of the "YAGI" type shall be provided for mounting either on a feed-through connector on top of the MU housing

or on a feed through connector on top of the fall-out shelter. In the latter case a coaxial transmission line shall be provided to connect the MU housing to the shelter feed-through. A similar line shall extend from the MU housing roof fitting inside to the long-haul terminal location.

C.5.3.2 Long-Haul Transceiver

The long-haul transceiver shall be connected through a transmit/receive switch to the long-haul antenna. The receiver shall be muted until de-muted by the receipt of a signal. Transmission shall be half-duplex digital. Data bursts received shall be recorded via a data modem on a terminal cassette tape facility and also in the terminal buffer storage. Code shall be asynchronous ASCII at a data rate to be specified. Messages or commands received shall be displayed from cassette on the terminal Video Display Unit (VDU). The tape cassette shall be built into the VDU.

C.5.4 The Control Subsystem

The control subsystem consists of a console mounted in the MU which contains or controls the following facilities:

1. A telephone facility
2. A voice magnetic tape facility
3. A video display terminal with keyboard and cassette unit
4. A microphone and speech amplifier
5. Modulation monitor
6. Monitor scope sampling LF RF output
7. Switchboard control of LF audio input
8. Tone burst encoder and control for demute capability on LF transmission
9. Removable LF receiver
10. Removable AM/FM/TV monitor receiver
11. A digital 24-hour clock
12. Status display panel

The console shall be so located and laid out that a single operator can control all MU Transmission, reception and monitoring functions; and, can visually observe LF transmitter meters, lights and displays, AC power distribution and control panels.

A switch shall be provided for actuating a control circuit to the LF antenna tuning unit location for grounding the tower. This circuit shall be interlocked with the LF transmitter high voltage control circuit, and, if the antenna is jointly used, with the broadcast transmitter high voltage control circuits to avoid actuation of the grounding relay while the tower is energized.

C.5.5 <u>Test and Status Display Subsystem</u>

Test equipment shall be available including:

1. Oscilloscope
2. Audio Signal Generator
3. Frequency Counter
4. RF Power Meter
5. Volt Ohmmeter

A small maintenance space shall be provided in the MU to do bench type testing and for storage of selected spare parts, modules and tools .

A small lighted status display panel mounted on the control console (Paragraph C.5.4) shall provide a central display of such critical circuit conditions throughout the MU as it is possible to remote to that point. Information displayed at this point will depend on what level of build-in test equipment (BITE) is available in the component equipments acquired and included in the MU as well as the final system design requirements and operational procedures to be followed.

C.5.6 <u>Power Distribution Subsystem</u>

Power provided the MU in the fall-out shelter shall be 480 VAC, 3-Phase. A voltage regulator shall be provided to prevent the varying load of the single-channel modulation of the SSB transmitter from adversely affecting the operation of other equipment.

Regulated output shall be 120 volts, 60 cycles, single phase and 240 volts, 60 cycles, single phase. A power control panel shall be wall mounted inside the MU with voltage, current and frequency meters visible to the MU console position. Secondary power distribution circuits shall be provided with protective circuit breakers.

C.5.7 Transporter Subsystem

The transporter subsystem shall consist of a 15-foot minimum length transportable equipment shelter mounted on a low-boy type of trailer for hauling by a standard tractor truck prime mover. The shelter shall be so mounted that it can be removed from the low-boy should that become desirable. The shelter shall contain the Transmitter Subsystem, the Reception Subsystem, the Long-Haul Terminal Subsystem, the Control Subsystem, the Test and Status Display Subsystem, and the Power Distribution Subsystem. The shelter, with its transporter and the transporter prime mover shall make up the MU. The shelter with or without its transporter (low-boy) shall, when at a host station, normally be housed inside the MU vault of the fall-out shelter.

C.5.7.1 Equipment Shelter

The actual size of the equipment shelter shall be determined during detailed system design such that it and its contents, the transporter and the fall-out shelter provided for its protection are mutually compatible, as to size, shape and utility. The shelter shall be of heavy duty construction on a heavy duty skid to which small metallic rollers are fitted. It must be capable of withstanding multiple moves over primary and secondary roads. Rear entry shall be provided for equipment and side entry for personnel. The shelter interior shall be paneled. The exterior shall be weather proof and no-seam metallic to form an electrostatic shield for EMP protection over a minimum of 1 5/8-inch styrofoam or similar insulation. The floor shall be vinyl-asbestos tile. All doors and ventilation openings shall be sealed on all sides with air-tight, dust-out weather stripping.

C.5.7.2 Unloading/Loading the Shelter

The fall-out shelter MU vault shall normally house an operable equipment shelter, and its low-boy trailer. If it is necessary to remove the shelter from the trailer, outside of the fall-out shelter, a crane shall connect to lift-points on the shelter skid; or, the shelter may be winched off on its metallic rollers down rear trailer ramps.

C.6 THE RECEIVER SUBSYSTEM

The receivers shall provide the capability to receive and demodulate LF (160 to 190 kHz) signals generated at the distant transmitting site(s). Receivers shall normally be in a muted condition until activated by an actual warning or test transmission.

Operation shall be single-sideband (upper side-band only) on ten spot frequencies in the range 160 to 190 kHz.

C.6.1 Tuning

The receiver shall be pretuned and capable of being switched to any three of the ten spot frequencies. A generically labeled switch (i.e. A through C or 1 through 3) shall provide for channel selection. Channel frequencies shall be designated on a rear mounted plate. Frequency A shall be that assigned to the transmit zone for the propagation area to which each receiver is assigned. Frequencies B and C shall be those assigned to immediately adjacent transmit zones - for contingencies. Frequencies shall be as specified in Paragraph C.2.2. A receiver incremental tuning (clarifier) capability of ± 300 Hz shall be available, to correct for transmitter or receiver drift.

C.6.2 Duty Cycle

The LF receiver shall be capable of continuous operation.

C.6.3 Frequency Stability

The LF receiver shall be capable, after an initial 30 minute warm-up period, of maintaining channel frequency within ± 100 Hz between 0 and 50 degrees C.

C.6.4 Automatic Gain Control (AGC)

An AGC circuit shall be provided with a fast attack, slow decay time constant. The audio output shall not vary more than 3 dB over a RF input range of 5 microvolts to 2 volts.

C.6.5 Sensitivity

The receiver shall provide a minimum signal plus noise-to-noise, (S+N)/N, ratio of 10 dB at the audio output with an RF input of 10.0 microvolts RMS at the antenna input terminal from a signal source impedence of 300 ohms.

C.6.6 Output Noise Quieting versus Input Level

The (S+N)/N ratio shall increase linearly in response to a linear increase in signal input level from 10 to 50 dB.

C.6.7 Selectivity

The selectivity shall be from 300 Hz to 2400 Hz (2.1 kHz) at the -6 dB points with a skirt selectivity factor of 2.0 or less at the -60 dB points.

C.6.8 Image Rejection

The rejection of image signals shall be at least 40 dB.

C.6.9 Audio Output Level

The receiver shall be capable of an audio output of 2.0 watts into an internal speaker. Provisions shall be made for an external 600 ohm output connection.

C.6.10 Hum Level

The hum and receiver noise shall be at least 55 dB below the rated audio output signal level.

C.6.11 Harmonic Distortion

Total audio distortion shall not be greater than 2.0 percent at the rated output level.

C.6.12 Antenna

The receiver shall contain an internal antenna. Provision shall be made for connection to an external loop antenna with an impedence of 300 ohms nominal, balanced.

C.6.13 Receiver Power

The receiver shall operate from single phase, 120 volt ± 10 percent, 60 Hz, alternating current (primary) with the capability to automatically switch to an internal NICAD battery for back up power.

C.6.14 Tone Activated Demuting

The receiver shall remain in the muted condition (no audio output) until receipt of two separate, distinct tone inputs. A 3 second interval for each tone shall be required to demute the receiver so as to preclude demuting on transient tones. Once demuted, the receiver shall remain in operation until another tone is transmitted to remute the receiver. A manual demuting capability shall be available.

C.6.15 Tone Activated Alarm

In conjunction with the tone activated demuting system, a set of normally open external contacts shall be provided which will close and activate an audible/visual alarm system simultaneously with the demuting action. This feature will allow individual monitoring activites to attach an alarm system of their own choosing to alert an operator who is temporarily absent from the vicinity of the receiver.

C.6.16 Electromagnetic Pulse (EMP) Protection

The receiver shall be provided EMP protection within "state of the art" technology. Transient voltage protection and maximum shielding shall be provided throughout.

C.7 THE LOGISTICS SUBSYSTEM

The system shall be supported by a number of logistics centers to be specified. At the present time, it is proposed that these centers be located at the DIDS Station at Edgewood Arsenal, Maryland, and at the Federal Regional Centers throughout the USA. These logistics centers will act to supply trained operating and maintenance personnel, spare parts, materials, transportation, and fuel to the MUs functioning within their jurisdictions. While some field maintenance will be possible at the host broadcast station locations, all depot type maintenance shall be performed at the logistics centers. The actual resources for each logistics center will depend on detailed system design which is to be accomplished during Phase 2 of the acquisition plan.

APPENDIX D

SAMPLE CALCULATIONS

APPENDIX D-SAMPLE CALCULATIONS

D.1 GENERAL

A sample of the calculations used to determine the electrical height, field intensity efficiency, radiation resistance, current, voltage, reactance, impedance, and bandwidth values shown on Table 4-1 of Section 4 and the field intensity at the contours of Figure C-2 are included in this Appendix.

D.2 WAVELENGTH CALCULATIONS

The usable LF frequency band for the LFMWS will be 160 to 190 kHz. The following formula is used to calculate the wavelength:

$$\text{Wavelength } (\lambda) = \frac{\text{velocity of light (c)}}{\text{frequency (f)}} \qquad \text{(D-1)}$$

$$\lambda_{160} = \frac{9.8424 \times 10^{8} \text{ ft/second}}{160 \times 10^{3} \text{ cycles/second (Hz)}}$$

$$= 6151.5 \text{ feet (1875 meters)}$$

A quarter wavelength at 160 kHz = 1538 feet (468.8 meters)

$$\lambda_{190} = \frac{9.8424 \times 10^{8}}{190 \times 10^{3}} = 5180 \text{ feet (1578.9 meters)}$$

A quarter wavelength at 190 kHz = 1295 feet (394.7 meters)

D.3 FIELD INTENSITY AND POWER EFFICIENCY CALCULATIONS

Figure D-1 provides the values of field intensity in millivolts/meter (mV/m) that will typically be provided by a vertical antenna driven by a 1 kW transmitter when measured at a distance of one mile. This plot assumes that the vertical antenna uses a ground radial system with 120 (3 degree azimuth spacing) radial elements, each a quarter of a wavelength long. If the ground radial system uses radials that are shorter than $\lambda/4$, Figure D-2 is used to determine the amount by which the field strength shown on Figure D-1, should be reduced.

If the antenna is assumed to have a height of 500 feet and to operate on an LF frequency of 160 kHz, the electrical height of the antenna would equal 0.081λ $(500 \div 6151.5)$. This may be expressed as 29.3 degrees $(0.081\lambda \times 360)$. Assuming the ground radial system has

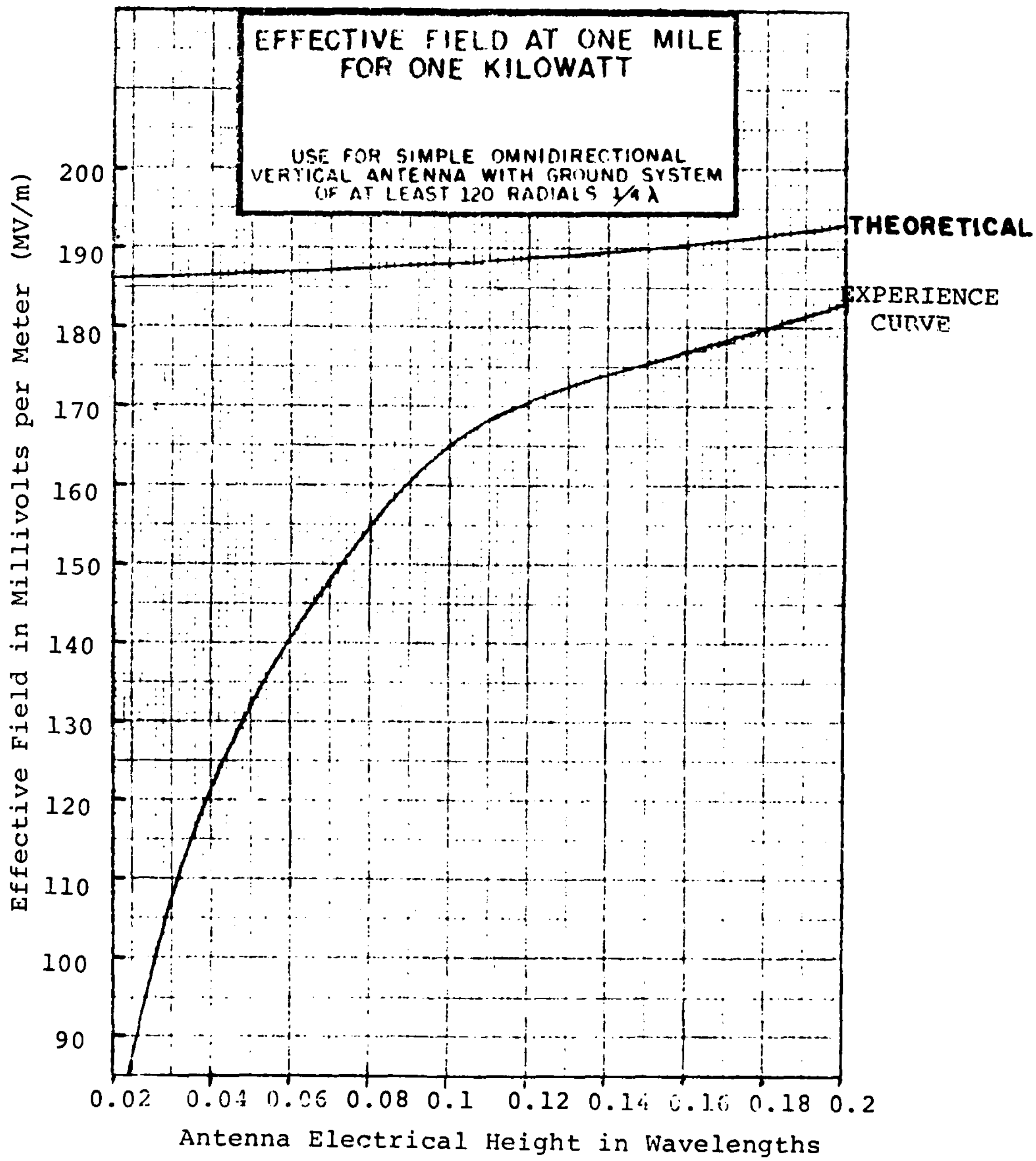


Figure D-1. Field Strength (At one Mile) Versus Antenna Electrical Height for One kW Power Input

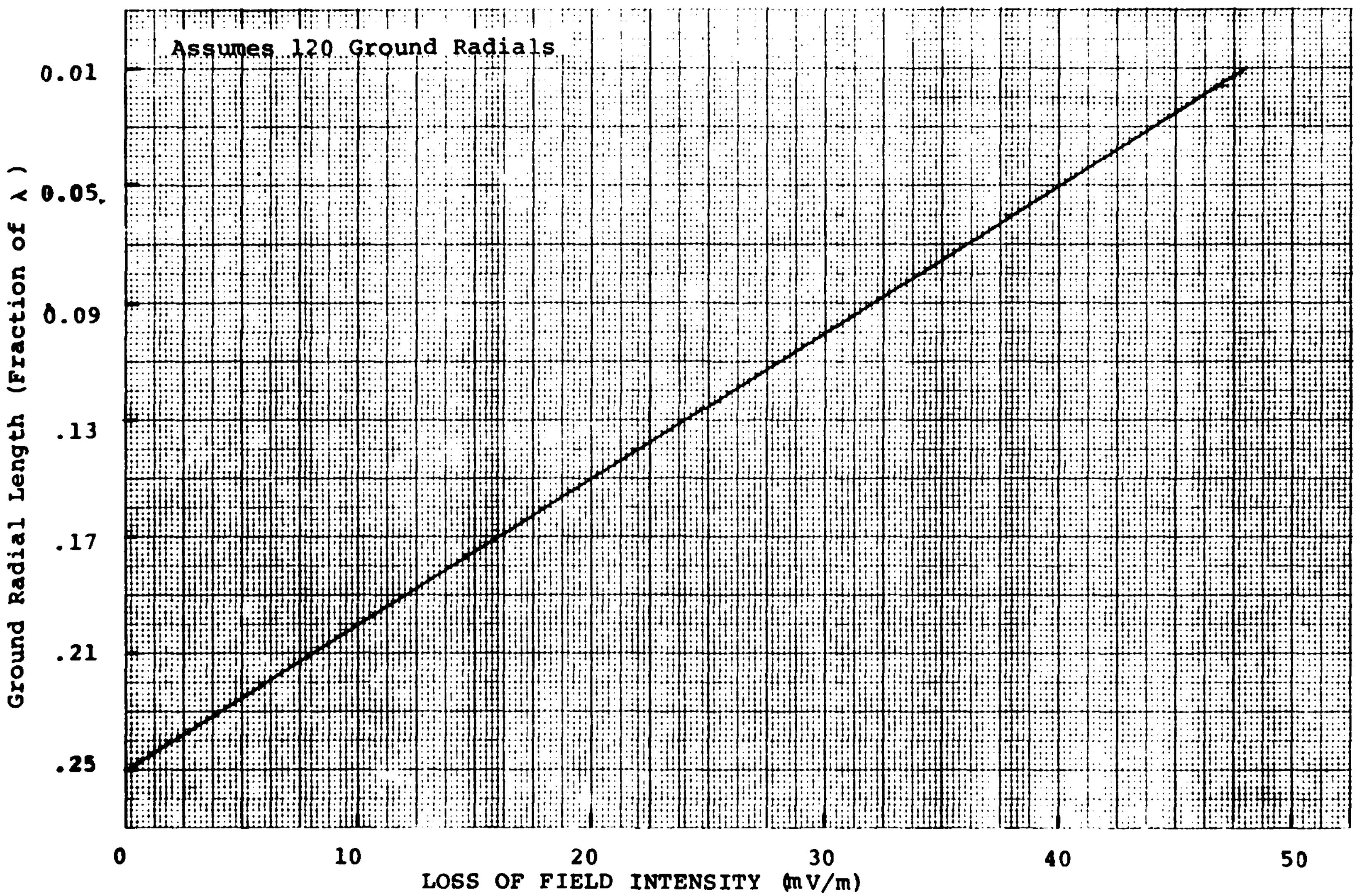


Figure D-2. Correction for Ground Radial System Shorter than One Quarter Wavelength (Reference Figure D-1).

a radius equal to the antenna electrical height, (which is typically the case with AM medium frequency broadcast stations), the field intensity at one mile can be determined from Figures D-1 and D-2. From Figure D-1, it can be seen that an antenna electrical height of 0.081λ intersects the curve at 155.5 mV/m.

The correction factor for the short (0.081λ) radial system is derived from Figure D-2 and found to be -34.5 mV/m. Thus, effective field strength at one mile is projected to be 155.5-34.5 or 121 mV/m.

The radiated field efficiency (E_{rf}) is calculated by the following:

$$E_{rf} = \frac{\text{mV/m value at 1 mile} \times 100}{186.3 \text{ mV/m}} \qquad \text{(D-2)}$$

The number 186.3 is the projected value for a system with 100% efficiency.

Using formula D-2, the E_{rf} for the 500 foot antenna equals $(121 \div 186.3) \times 100$, or 65%.

If an antenna coupling loss of 0.5dB is assumed, the 65% is reduced by a 0.945 factor to 61.4%.

The radiated power efficiency (E_{rp}) is determined from the following:

$$E_{rp} = \left(\frac{E_{rf}}{100}\right)^2 \times 100$$

Thus, the radiated power efficiency for the 500 foot antenna is projected to be $(61.4 \div 100)^2 \times 100 = 37.7\%$.

D.4 CALCULATION OF PROPAGATION RANGE (RADIUS)

An estimation of the range that could be provided by the radiation of the 500 foot antenna can be derived from Figures D-3, D-4, and D-5 (FCC developed plots).

If it is assumed that the transmitter puts out 25 kW of RF power, the power ratio for this example becomes 25 kW $\div$ 1 kW or 25. The field intensity will increase by the square root of the

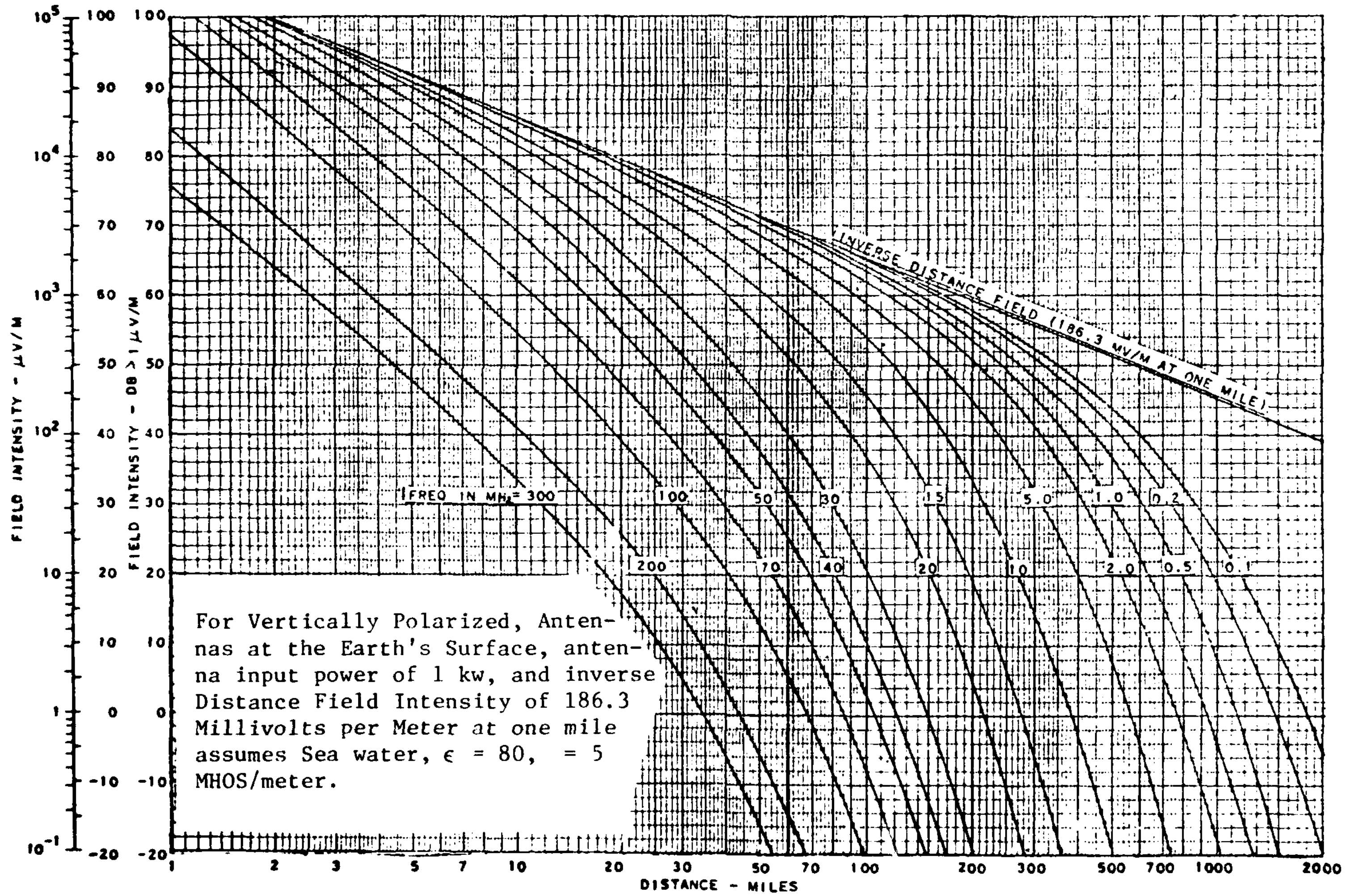


Figure D-3. Ground-Wave Field Intensity Versus Distance Over Sea Water for Various Frequencies (0.1 to 300 MHz)

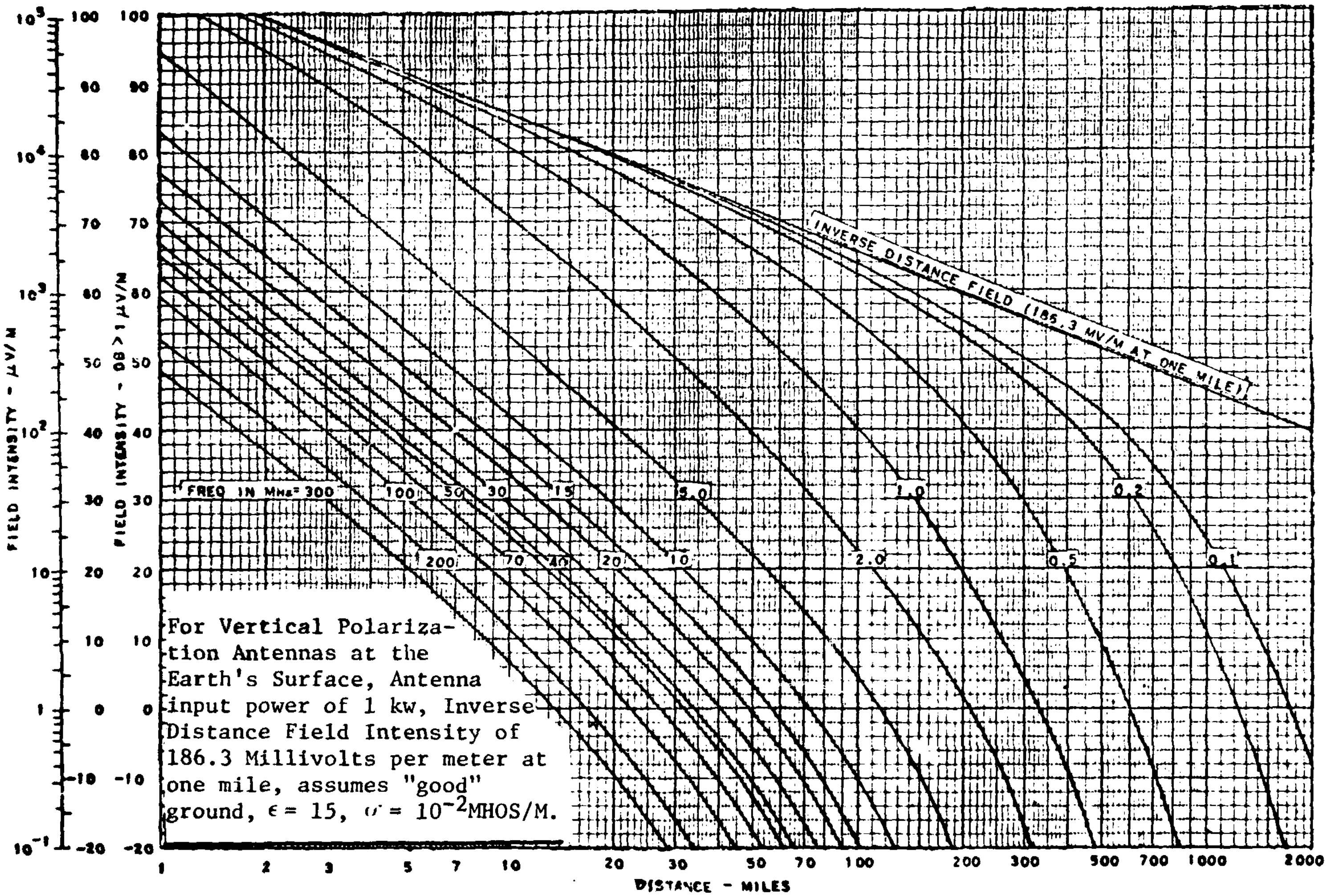


Figure D-4. Ground-Wave Field Intensity Versus Distance Over Good Conducting Earth for Various Frequencies (0.1 to 300 MHz)

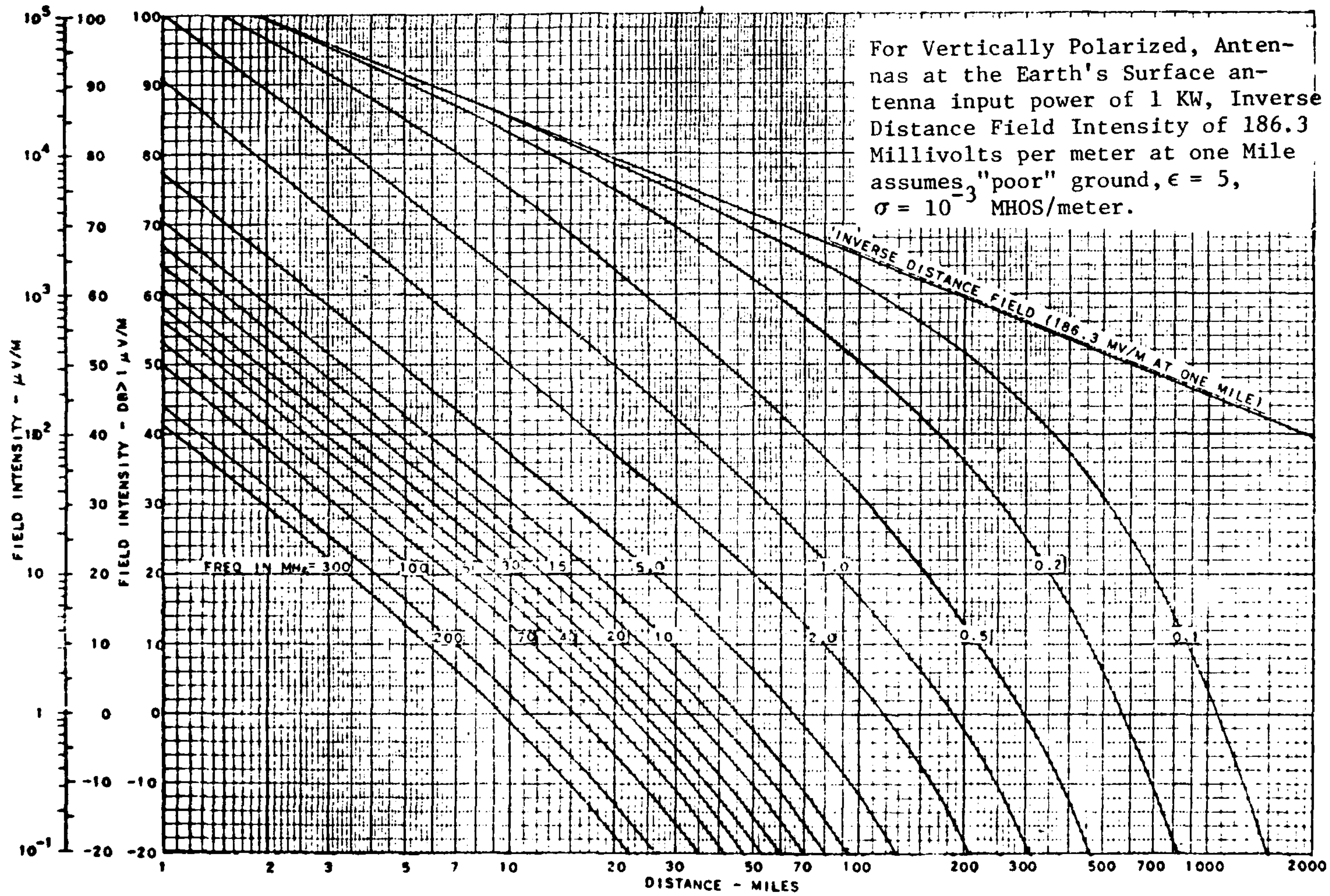


Figure D-5. Ground-Wave Field Intensity Versus Distance Over Poor Conducting Earth For Various Frequencies (0.1 to 300 MHz)

power ratio which is 5 for a 100% field intensity efficiency or 3.07 for a 61.4% efficiency (from 5 x .614).

From Figure D-4, the range at which 350 microvolts/meter (μV/m) can be provided over good earth, is derived. If we have 100% efficiency and 1 kW applied to the vertical antenna, 186.3 millivolts per meter (mV/m) will be available at one mile.

To determine the range at which 350 μv/m will be provided, the Y axis must be translated to the equivalent of the new conditions, namely 25 kW and 61.4% field intensity efficiency. The 350 μv/m value is divided by the 3.07 field intensity increase factor, derived above, to determine the new Y axis value for Figure D-4. This value is 114 μv/m and is converted to the dB scale by 20 $\log_{10} \frac{114}{1}$ or 41 dB above 1 μv/m. The horizontal intersection of this value with a projected 0.16 MHz on Figure D-4 (good earth conductivity) provides a range of 470 miles.

D.5 *BANDWIDTH CALCULATIONS*

The calculation of antenna bandwidth should take into consideration both the static antenna bandwidth (bandwidth of the antenna as an isolated element) and operating system bandwidth. The operating antenna system bandwidth results from the combination of static antenna conditions, the system losses, and the *interconnection* to the ground system and the transmitter.

The static bandwidth can be approximated by calculating the base resistance (R_b), the antenna characteristic impedance (Z_o), the antenna base reactance X_a, the static bandwidth quality factor (Q_s), and use R_b, Z_o, X_a and Q_s to derive static bandwidth (BW_s).

$$R_b = \frac{H_d^2}{312} \qquad \text{(D-4)}$$

where: H_d is antenna height in degrees
312 is a constant derived empirically

$$Z_o = 138.2 \log_{10} \frac{H}{D_e} + 23.2 \qquad \text{(D-5)}$$

where: H is antenna height linear measure

D_e is effective diameter of the antenna

138.2 is a constant

23.2 is a constant

$$x_a = -j\ Z_o \text{ Cot } H_d \qquad \text{(D-6)}$$

$$Q_s = \frac{x_a}{2R_b} \qquad \text{(D-7)}$$

The factor 2, is used to account for a matching drive resistance.

$$BW_s = \frac{\text{LF Operating Frequency}}{Q_s} \qquad \text{(D-8)}$$

The operating system bandwidth (BW_{os}) can be derived from the calculated power efficiency of an antenna system by using the plot on Figure D-6 to determine K.

$$BW_{os} = BW_s\ (K)$$

The following steps are used to estimate the operating bandwidth of a 500 foot antenna with a diameter enhanced by drop-wires to 20 feet, that operates at 160 kHz. The electrical height is 29.3 degrees.

$$R_b = \frac{(29.3)^2}{312} = 2.75 \text{ ohms}$$

$$Z_o = 138.2 \log_{10}\frac{500}{20} + 23.2 = 216 \text{ ohms}$$

$$X_a = -j\ 216 \cot 29.3 = -j\ 385 \text{ ohms}$$

$$Q_s = \frac{385}{2\ (2.75)} = 70$$

$$BW_s = \frac{160 \times 10^3}{70} = 2286 \text{ Hz}$$

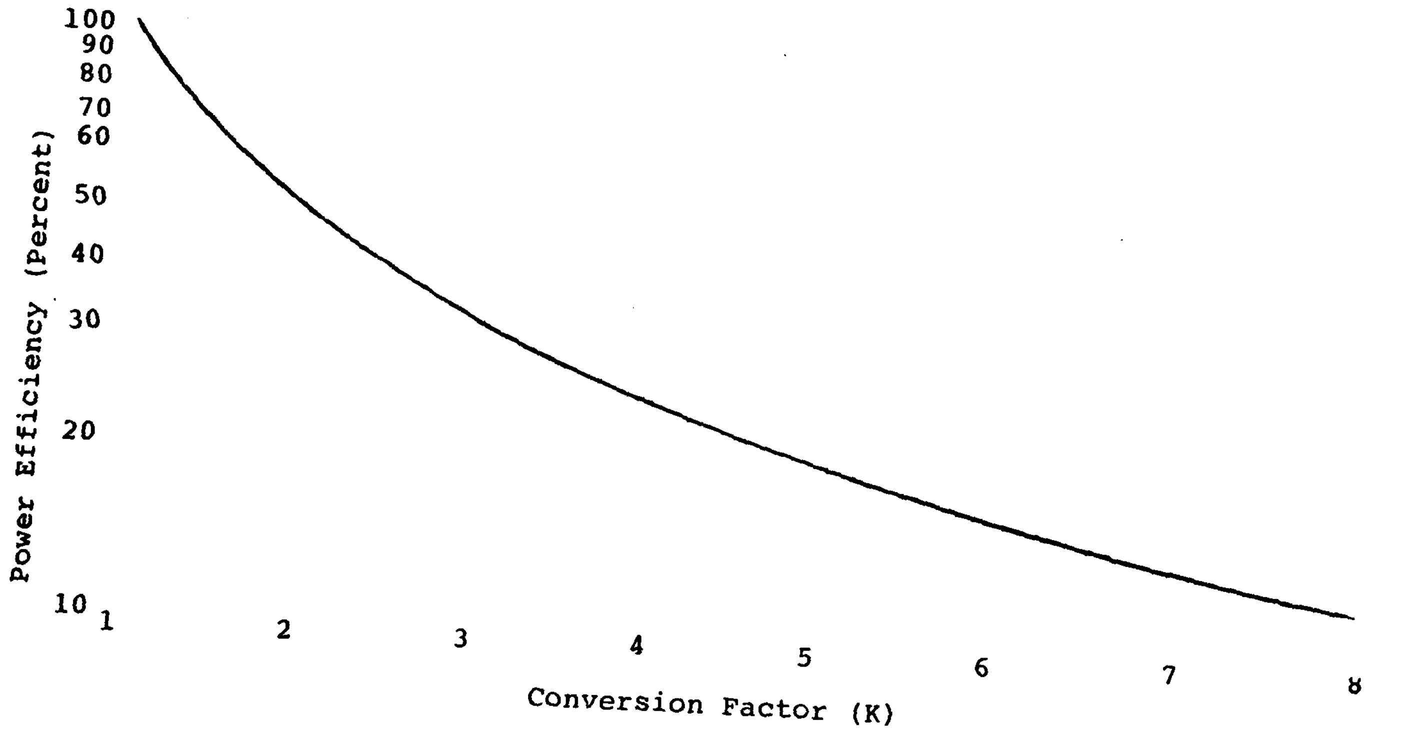


Figure D-6. Bandwidth Conversion Factor (K) for Converting Static Bandwidth to Operating System Bandwidth

The power efficiency of the 500 foot antenna is derived on page D-4. The power efficiency is 37.7%. Using this efficiency value to determine K from Figure D-6, a K value of 2.6 is derived, thus:

$$BW_{os} = 2286\ (2.6) = 5944 \text{ Hz or } 5.94 \text{ kHz}$$

D.6 CURRENT AND VOLTAGE CALCULATIONS

The power capability of an antenna is primarily due to its voltage limitation at the lowest operating frequency. For the 500 foot antenna with the drop-wires enhancing its diameter to 20 feet the base resistance is 2.75 ohms and the reactance is -j 385 ohms at 160 kHz.

$$I = \sqrt{\frac{\text{Power in watts}}{R_b}} \qquad \text{(D-9)}$$

$$E_{ave} = IX_a \qquad \text{(D-10)}$$

Substituting the above numbers in formulae D-9 and D-10:

$$I = \sqrt{\frac{25,000}{2.75}} = 95 \text{ amperes}$$

$$E_{ave} = 95 \times 385 = 36,700 \text{ volts or } 37 \text{ kV}$$

$$E_{peak} = 37 \times 1.41 = 52 \text{ kV}$$

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MOBILE LOW FREQUENCY WARNING SYSTEM FEASIBILITY ANALYSIS — UNCLASSIFIED

Computer Sciences Corporation, Falls Church, VA 22046
DCPA01-79-C-0264 Work Unit 2234H November, 1980 236 p.

This report presents the results of a technical analysis and a cost estimate for a Mobile Low Frequency (LF) Warning System which is survivable against enemy attack through the use of redundancy and dispersion. The technical feasibility is shown based on shared use of AM, FM or TV broadcast station facilities under Program D-Prime by LF mobile units to blanket the contiguous 48 states with warning messages relayed from the National Warning Centers, or to warn of impending man-made or natural disasters and to coordinate recovery operations. Alternatives to the system architecture are discussed, and a preliminary system performance specification and cost estimate are included.

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